

HYDROLOGY FOR FEASIBILITY REPORT
BALLONA CREEK CHANNEL AND
SAWTELLE-WESTWOOD CHANNEL, CALIFORNIA
LOS ANGELES COUNTY DRAINAGE AREA

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
FEBRUARY 1979

SPDED-H (28 Feb 79) 1st Ind

SUBJECT: Hydrology for Feasibility Report, Ballona Creek Channel and
Sawtelle-Westwood Channel, Los Angeles County Drainage Area,
California

DA, South Pacific Division, Corps of Engineers, 630 Sansome Street,
Room 1216, San Francisco, California 94111

TO: District Engineer, Los Angeles, ATTN: SPLED-HE

3 AUG 1979

The peak discharges presented in tables 14 and 15 are approved for use
in feasibility studies.

FOR THE DIVISION ENGINEER:

1 Incl wd

John E. Wanket
J. E. WANKET
for Chief, Engineering Division



DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
P. O. BOX 2711
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11-19-46

SPLED-HE

28 February 1979

SUBJECT: Hydrology for Feasibility Report, Ballona Creek Channel and
Sawtelle-Westwood Channel, Los Angeles County Drainage Area,
California

Division Engineer, South Pacific
ATTN: SPDED-H

1. The inclosed report presents the development of hydrology for use in feasibility studies on Ballona Creek Channel and Sawtelle-Westwood Channel.
2. Approval of the peak discharges listed in tables 14 and 15 for use in the feasibility studies is requested.

FOR THE DISTRICT ENGINEER:

1 Incl (trip)
as

NORMAN ARNO
Chief, Engineering Division

	Table ¹⁴ 100-yr (EP)	100-yr (FIS)
US Sepulveda US	40,000	37,200
US Fairfax US	18,400	17,100
US ^{US} Santa Monica Fwy	20,800	19,300

To L.A. County
6-1-79

Based on 1951-1978 record

$$C.R. Q_{100} = 34,100$$

$$E.P. Q_{100} = 36,900$$

$$\text{ratio } \frac{34,100}{36,900} \approx .93$$

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FEASIBILITY REPORT
HYDROLOGY FOR BALLONA CREEK CHANNEL
AND
SAWTELLE-WESTWOOD WATERSHED
LOS ANGELES COUNTY, CALIFORNIA

I. INTRODUCTION

1-01. PURPOSE AND SCOPE.

a. This report presents hydrology on which a determination of the magnitude of the flood problem can be made and alternative plans evaluated for Ballona Creek channel. The hydrologic map is shown on plate 1. This study had four major objectives: (1) to review and update previously determined meteorologic and hydrologic characteristics; (2) to develop methods and techniques with which to describe the runoff process; (3) to determine the standard project flood peak discharges and discharge frequency values at selected locations along the channel for (a) present ~~and ultimate~~ basin development with existing bridge and channel conditions and the existing storm drain network; (b) ^{future} ~~present~~ basin development with ^{an expanded} ~~the existing~~ storm drain network and ^{existing} ~~the~~ channel and bridges ^{conditions} ~~upgraded to carry the required flow~~; (c) future basin development with an expanded storm drain network and the channel and bridges upgraded to carry the required flow; and (4) to describe the existing and possible future flood problem along Ballona Creek with respect to overflow locations. Inherent in this study was the determination of the changes in the runoff process which occurs when a watershed undergoes urbanization and storm drain systems are installed. Throughout this report, the term "present conditions" refers to basin development in 1978; likewise, "ultimate conditions" refers to ultimate future conditions in 2078. Also, "restricted conditions" refers to the channel and bridges as they exist today; likewise, "unrestricted conditions" refers to design conditions where all flows entering a concrete-lined channel will be efficiently conveyed downstream without overflow.

b. Determination of the degree of flood protection on Ballona Creek channel indicated a possible deficiency for the Sawtelle-Westwood channel. This watershed was studied in detail after completion of the Ballona Creek channel portion, hence a more detailed runoff model was necessary. The hydrologic map for the Sawtelle-Westwood watershed, plate 2, shows the redefined subareas used to determine discharges for this part of the study. This study had two major objectives: (1) to determine standard project flood peak discharges and discharge frequency values at selected locations along the channel for (a) present ~~and ultimate~~ basin development with existing bridge and channel conditions and the existing storm drain network; (b) ^{future} ~~present~~ basin development with ^{an expanded} ~~the existing~~ storm drain network and ^{existing} ~~the~~ channel and bridges ^{conditions} ~~upgraded to carry the required flow~~; (c) future basin development with an expanded storm drain network and the channel and bridges upgraded to carry the

required flow; and (2) to describe the existing and possible future flood problem along the Sawtelle-Westwood channels in terms of overflow locations.

c. This study was coordinated with the Los Angeles County Flood Control District, and the City of Los Angeles.

1-02. PREVIOUS REPORTS. A list of U.S. Army Corps of Engineers hydrology reports follows.

a. Hydrology, Sawtelle-Westwood Systems including Sepulveda Canyon, 1 July 1948.

b. Hydrology for Centinela Creek Channel (Ballona Creek Basin), September 1955.

c. Hydrology for Benedict Canyon Channel and Higgins and Coldwater Canyons Channel, April 1960.

d. Completed flood insurance studies in the watershed area. Flood Insurance Studies, Los Angeles California, Areas 2, 3, 7, 8 dated February-June, 1971. There are additional reports which refer to some aspect of hydrology in the watershed. These reports are acknowledged but not listed.

II. GENERAL DESCRIPTION OF DRAINAGE AREA

2-01. PHYSIOGRAPHY AND TOPOGRAPHY.

a. The Ballona Creek watershed, approximately 121 square miles in size, is located in western Los Angeles County. The creek serves as a collecting channel for numerous small canyons on the southerly slopes of the Santa Monica Mountains and for runoff from the streets and storm drains of the highly developed urban communities of West Los Angeles, Beverly Hills, Culver City, Hollywood, and part of the City of Los Angeles west of the downtown business district. Approximately 20 percent of the drainage area is composed of foothills and mountains which are characterized as gently sloping terrain, dissected by steep canyons. The remaining 80 percent of the watershed is highly urbanized coastal plain. Elevations in the mountainous area range from 400 feet to 1,800 feet, and in the coastal plain, from sea level to 400 feet. Average gradients of canyon channels range from 250 to 400 feet per mile, whereas the average slope of the valley floor is about 40 feet per mile. Profiles for various reaches of Ballona Creek are shown on plate 3.

b. Several areas along Ballona Creek channel have been subject to flooding. Prior to construction of Ballona Creek Flood Control Channel in the 1930's, floodflows collected from the canyons in the upper reaches of Ballona Creek were confined to an entrenched natural watercourse until reaching a flat, marshy area located near the present-day intersection of La Cienega Boulevard and the Santa Monica Freeway (see pl. 1). Flows escaping this area traveled downstream and combined with flows from another marsh located east of the present Rodeo Road-La Brea Avenue intersection (see pl. 1). Proceeding further downstream in a reach of deeply entrenched channel, flood peaks were finally dissipated in the flat, marshy area of Ballona Lagoon, where the present-day Marina Del Rey is located.

2-02. AVAILABLE MAPPING. The best general contour coverage of the study area available for this study was the 1:24,000 scale series of topographic maps published by the U.S. Geological Survey (USGS). These maps have contour intervals of 10-20 feet. Additional mapping, at a scale of 1 inch = 400 feet, was obtained from the City of Los Angeles. The city's maps have a contour interval of 5 feet for elevations less than 700 feet and a 25-foot interval for elevations greater than 700 feet. A mapped strip bordering the freeways in the study area was available from California Department of Transportation. Other available topographic mapping includes USGS 1:24,000 orthophoto quads published in 1969 and aerial photographs dated 1975.

2-03. GEOLOGY. The boundaries of the Ballona Creek drainage area include the Santa Monica Mountains to the north and the Baldwin Hills-Inglewood area to the south. The western boundary is a series of low ridges and mesas about 1-1/2 miles inland from the Pacific Ocean, which

extend north-south from the Santa Monica Mountains through the coastal plain to Venice and across Ballona Creek easterly to the Baldwin Hills. The eastern boundary extends from the crest of the Santa Monica Mountains south and west along a series of low hills near central Los Angeles to the Baldwin Hills.

The Santa Monica Mountains are about 45 miles long and are composed of marine sediments of late Cretaceous to Pleistocene age and Miocene volcanic rocks overlying basement rocks of later Triassic age. A broad alluvial plain extends south from these mountains to the Ballona Gap near Culver city. This plain is composed of Pleistocene and recent marine and non-marine sediments, described as silt, sand and gravel. These sediments are exposed in many of the low hills and mesas formed by erosion of the plain by recent streams. The thickness of these sediments varies from 200 feet in the vicinity of Ballona Creek to about 11,000 to 12,000 feet in the vicinity of the Los Angeles River and the Rio Hondo, a few miles east of the drainage area.

The Baldwin Hills are composed of marine and non-marine sediments of Pliocene and Pleistocene age. The eastern limits of the drainage area, close to Central Los Angeles, are composed of the marine sediments of late Cretaceous to Pleistocene age, overlying Basement Rock of late Triassic age at the eastern edge of the Santa Monica Mountains and marine and non-marine sediments of Pleistocene and Recent age along the low hills extending south and west to the Baldwin Hills.

All of the sediments mentioned above are underlain by older marine sediments of Miocene and Pliocene age, which have a maximum thickness of 15,000 to 20,000 feet in various portions of the drainage area.

Two major faults are found in the drainage area. The Newport-Inglewood fault zone extends through the Baldwin Hills from the southeast, across the coastal plain northwest to the Cheviot Hills, near Culver City. The Malibu Coast-Santa Monica fault extends in an east-west direction from the Pacific Ocean, skirting the edge of the Santa Monica Mountains to their eastern limit, then merges with the Raymond Hill fault. Both of these faults act as ground water barriers.

2-04. VEGETATION. Vegetation in the Ballona Creek watershed consists of remnant upland plant communities in the steep undevelopable areas of the upper drainage; plantings of grasses, shrubs, and trees associated with urban developments; and aquatic, intertidal, and upland vegetation associated with marina development and undeveloped lands near the mouth of the creek. Of this vegetation, the ornamental plantings associated with urban development are most abundant. The upland vegetation provides fair to moderate protection from erosion, but severe erosion can result if this cover is distributed through improper management.

2-05. LAND USE. With the exception of parts of the foothill and mountain areas, the Ballona Creek watershed is highly urbanized at present. Further development is expected in the future in the foothill areas, and a change from relatively low density residential to higher density residential, industrial, and commercial use is expected in a significant portion of the flat valley. Ultimate land-use projections, shown on plate 4, were based on the adopted plans of the Cities of Los Angeles, Culver City and Santa Monica. These plans have been combined and mapped at a common scale in the Southern California Association of Governments (SCAG) Regional Development Guide, adopted in 1972.

2-06. RUNOFF CHARACTERISTICS. None of the watercourses in the study area flow perennially from natural sources. Other than urban and industrial effluent, runoff occurs only during and immediately following rains because climatic and drainage area characteristics are not conducive to continuous natural flow. Runoff increases rapidly in response to rainfall excess. During large floods, man-made debris is often transported downstream, building up on bridge piers, especially at the Sepulveda Boulevard and Sawtelle Boulevard crossings.

2-07. FACTORS AFFECTING RUNOFF.

a. Freeways. The Hollywood, Harbor, Santa Monica, San Diego, and Marina Freeways all traverse the study area. A freeway may be both entrenched and elevated within a subarea. In general, freeways cause only minor obstructions or diversions to floodflows. ^{However,} ~~In addition,~~ new concrete center dividers constructed on the San Diego Freeway north of the Santa Monica Freeway interchange effectively block floodflows from crossing the freeway. Extensions of the new center dividers ^{Southward} ~~on the San Diego Freeway will effect the path of flow in Sepulveda Canyon.~~ If the new dividers are built on other sections of ~~entrenched~~ freeways, more diversions of floodwaters can be expected. ~~The impact of additional commuter systems which may be constructed in the future is unknown.~~

b. Storm Drain Systems.

(1) The study area is a maze of storm drain systems, many of which are interconnected. Inflow into the channels during a relatively small storm is almost exclusively storm drain flow; in which case, the rate of runoff is a function of the storm drain network characteristics and the amount of hydraulically connected impervious cover. Plates 5 and 6 show major trunk lines which discharge flows in excess of 100 cubic feet per second (cfs) into Ballona Creek and Sawtelle-Westwood channels. Tables 1 and 2 summarize by subarea, existing and proposed, storm drain systems which contribute 100 cfs or more to the Ballona Creek and Sawtelle-Westwood channels. The capacities used in this analysis were based on a water surface at the top of channel walls. Channels built by the U.S. Army Corps of Engineers are also included.

(2) It should be noted that the location of proposed storm drain inlets to the channels is important in maintaining efficient Ballona and Sawtelle-Westwood Creek conveyance systems. For example, location of a major inlet upstream of a bridge with restricted capacity may aggravate an existing capacity problem. Installation of the inlet downstream of the bridge, provided the channel capacity is sufficient, would circumvent the problem at that bridge.

(3) Most of the expected increased capacity for the future reflects the upgrading of the existing systems. The limited capacity of the existing covered channels reduces the ability of additional upstream storm drains to effectively convey flows.

c. Water Supply Reservoirs. The City of Los Angeles Department of Water and Power owns and operates water supply reservoirs in the northern foothill portion of the study area. Runoff from small flood events would probably be retained by the reservoirs; for standard project flood conditions, the reservoirs were assumed to be full. In any case, the contributing drainage area is small. Table 3 gives a summary of the pertinent data for these reservoirs. The locations of these reservoirs are shown on plates 1 and 2.

d. Bridges.

(1) The low chords of bridges crossing the Ballona Creek channel are, almost without exception below the top of the extended channel wall or the ground line, thus restricting the effective conveyance capacity of the channel. In entrenched reaches, where the surrounding ground slopes toward the channel, floodwaters will overtop or flow around the bridge and quickly return to the channel without significantly altering the flood hydrograph. Flood damage will be sustained in a rather limited area close to the bridge. Where bridges cross a leveed reach of channel, flows will overtop the levees and escape the channel, causing flood damage in the surrounding lowlands. Levee failure analysis indicates that if overtopped by approximately 6 inches of water for about 30 minutes, the Ballona Creek levees will be breached.

(2) It is possible that the old wooden bridges at Sepulveda and Sawtelle Boulevards, built in the late 1930's, will fail when overtopped. Time of failure would be uncertain, therefore, for this study, all bridges were assumed to remain intact. Plate 7 shows channel and bridge capacities along Ballona Creek channel. Plate 6 also shows channel capacities along Sawtelle-Westwood channel.

e. Future Conditions. Two factors are noted which will have a major impact on the expected increased runoff under future conditions.

(1) Partially completed and proposed storm drain systems will allow a greater flow to be conveyed more efficiently.

(2) Percent impervious cover will increase as the areal extent and density of urbanization increases.

f. History of Design and Construction of Ballona Creek channel.

(1) The design and construction history of Ballona Creek channel is somewhat obscure. The original set of design discharges for the channel were developed in the mid-1930's using a form of the rational method. At that time, the unit-hydrograph procedure was not used and the standard project flood had not yet been conceived. A modified rational method (Ultimate Q) was adopted as the best method by which the runoff hydrographs could be computed that would compensate for (expected) ultimate development. Optimized 24-hour-50 year rainfall was used to develop these design discharges. Channel and possibly bridge construction based on these values followed. The design discharges are listed in table 4.

(2) In 1949, the Los Angeles County Flood Control District (LACFCD) prepared a set of "Capitol Q's" (design discharges) for Ballona Creek. These discharges were also based on 24-hour-50 year rainfall. They are also listed in table 4 and compare favorably with the previous design discharges. It is not certain if these Capitol Q's were used as a basis for any design.

(3) In 1954, the Los Angeles District (LAD) computed standard project flood design discharges for expected future conditions on Ballona Creek (see table 4). These discharges were significantly greater than the previous design discharges and 1949 Capitol Q's in the upper reach (drainage areas less than about 50 square miles). For the larger drainage areas, all three studies resulted in similar discharges. Additional channel construction followed in the 1960's to increase channel capacities. It is believed that 1954 SPF discharges are the design discharges used to upgrade the conveyance capabilities of the Ballona Creek channel.

(4) In 1968, the LACFCD revised their Capitol Qs (see table 4). These discharges were comparable to the design discharges (1954 SPFs) for drainage areas less than 70 square miles. LACFCD undertook construction in the early 1970's to upgrade channel capacities in the upper reach from Fairfax Avenue to Burnside Avenue.

g. History and Design and Construction on Sepulveda (Sawtelle-Westwood) channel.

(1) In 1951 the U.S. Army Corps of Engineers initiated construction of the concrete lined channels shown on plates 1 and 2. Construction of this system was necessary to improve the conveyance efficiency within the watershed, and provide an outlet through the north

levee of the Ballona Creek channel. Almost the entire length of channel upstream of CP 114, plate 2 on the Westwood branch and the Sawtelle branch is covered. Channel capacities are shown on plate 6.

2-08. CLIMATOLOGY.

a. The western Los Angeles Area has a subtropical climate with mild winters and generally cool summers. Near the coast, the modifying influence of the Pacific Ocean is very prominent, and both the seasonal and daily temperature ranges are small--generally less than 15 degrees Fahrenheit. Frosts are uncommon, and snow is extremely rare. Temperatures near the coast seldom exceed 90 degrees F., although on occasion during late summer and fall, hot dry winds from the desert, known as Santa Anas, can reach the coast and send temperatures above 100 degrees F. A tabulation of normal meteorologic data and extremes of record for Los Angeles International Airport (a few miles south of the southwestern portion of the Ballona Creek basin), as compiled by the National Climatic Center, NOAA, is given in table 5.

b. Farther inland, the normal seasonal and daily temperature ranges are considerably larger, with generally cooler winter nights and much warmer summer days (although the absolute temperature extremes do not differ significantly from those of the coastal belt). Data published for Los Angeles Civic Center (table 5), which is located just beyond the eastern extreme of the Ballona Creek basin, is considered climatically representative of the northern and eastern inland portions of the drainage.

c. Mean annual precipitation in the study area ranges from just over 13 inches in the southwestern corner of the basin to around 17 inches in the northeastern portions to more than 19 inches in the higher portions of the Santa Monica Mountains in the northwest corner of the drainage. More than 95 percent of the year's precipitation normally falls during the cooler months from November through April, with totally rainless periods very common during the summer months. The potential exists, however, for heavy local or tropical storm rainfall during the months July through October. The isohyets of mean annual precipitation over the region, prepared by LACFCD, is shown on plate 1. Tabulations by month of normal and extreme precipitation at Los Angeles Airport and Los Angeles Civic Center area given in table 5.

d. There are three basic types of storms which can affect the study region, although some individual storms may consist of a combination of types: general winter storms, local storms, and general summer storms.

(1) General winter storms usually occur during the period from November through April, with the highest frequency and intensity normally occurring from December through March. These storms, which supply the greatest percentage of southern California's rainfall,

usually originate over the north Pacific Ocean as the result of the interaction between polar and tropical air masses and move generally eastward across the North American west coast. This type of storm, which can last for several days, is often accompanied by widespread precipitation and nearly always reflects orographic influences (precipitation enhanced by uplift of moist air over mountains). Storms of this type which originate in the Gulf of Alaska and move into southern California from the northwest are generally of light or moderate intensity, with relatively low snow levels, while storms which originate in the sub-tropical Pacific near Hawaii and move into southern California from the west or southwest are often quite heavy and usually have much higher snow levels. (Since virtually the entire Ballona Creek drainage is below 1500 feet elevation, snow very seldom falls within the basin. Hence, snow and snowmelt are not considered to be of significance to the hydrology of Ballona Creek.) Some of the more significant general winter storms which have affected the western coastal plain of Los Angeles include those of January 1862, January, February, and March 1884, January 1886, October and December 1889, January 1890, February 1891, January 1905, January and March 1906, March 1911, January and February 1914, January 1916, December 1921, April 1926, February 1927, December 1933 - January 1934, February - March 1938, December 1940, March 1941, January 1943, January and March 1952, February 1954, January 1956, February 1957, February 1958, February 1962, April 1965, November 1965, November 1966, November 1967, January and February 1969, January 1973, December 1974, and February and March 1978.

(2) Local storms can occur at anytime of the year, but are less frequent during the late spring and summer in the coastal areas than during other seasons. These storms, which can occur either as isolated phenomena or during general storms, cover comparatively small areas but result in high-intensity precipitation for durations of 3 hours or less. Local summer type storms normally result from flow of moist tropical air into southern California from the south or east, while local winter type storms usually occur in conjunction with a storm cold front or a deep upper-level low pressure center. A few of the more significant local storms which have affected the coastal southern California areas include the thunderstorms of 12 October 1889 (Encinitas), 12 August 1891 (Campo), 18 July 1922 (Campo), 18 July 1922 (Squirrel Inn), 5 April 1926 (Opid's Camp), 20 February 1941 (Topanga Canyon), 14 March 1941 (near Fullerton), 21 October 1941 (Avalon), 3-4 March 1943 (Sierra Madre), 29 September 1946 (Cucamonga), 18 July 1955 (Vallecito), and 21 November 1967 (West Los Angeles).

(3) General summer storms have occasionally occurred in southern California during the summer or early fall months, usually in the form of tropical cyclones with originate off the west coast of Mexico and move northward toward California. A tropical storm of near hurricane intensity moved onshore near Long Beach, California on 25 September 1939. A number of other tropical storms have also had significant

effects upon the southern California coastal area, including those of August 1873, August 1889, October 1889, August 1908, September 1910, September-October 1921, September 1929, August 1935, August 1936, November 1941, September-October 1946, August 1951, September 1963, September 1967, and September 1972.

III. PRECIPITATION AND RUNOFF

3-01. PRECIPITATION RECORDS. An extensive network of precipitation stations is located in or near the Ballona Creek watershed (see pl. 1). Of the 30 stations listed in table 6, 15 are automatic recording gages. The Los Angeles-Ducommun Street station provides the longest record in the study area, 101 years starting in 1877.

3-02. STREAMFLOW RECORDS.

a. Two automatic recording gages are currently in operation within the watershed. Table 7 lists available pertinent information on active and inactive stream gaging stations. Locations of the two active gages are shown on plate 1. A tabulation of the annual peak discharges for the active gages is given in tables 8 and 9. A brief commentary on the two active gages follows.

b. The Ballona Creek above Sawtelle Boulevard stream gage has a continuous record from 1928 to present; however the station has been relocated three times, changing its contributing drainage area. The first location, at Centinela Boulevard (1928-36), had a drainage area of 112 square miles and included the Sepulveda Creek subbasin. From 1936 to 1967, the station was located at Sawtelle Boulevard and had a contributing area of 88.6 square miles. It should be noted that prior to construction of Sawtelle-Westwood channel in 1951, it was possible for overflow from Sepulveda Creek to enter Ballona Creek upstream of the gage (contributing drainage area = 111 square miles). This apparently occurred in March 1938; available information, however, is sketchy. In 1967, the gage was moved to its present location, 530 feet upstream of Sawtelle Boulevard (drainage area = 88.6 square miles). ^{89.5}

c. Streamflow records are available for Sawtelle-Westwood channel above Culver Boulevard from 1933 to the present, except for 1951 when the channel was being built. Prior to construction of Sawtelle-Westwood channel, the station was located at Charnock Road. The contributing drainage area is 23.0 square miles.

d. Records of the discontinued gages which existed in the basin were not useful. These records were either too short, not available or inaccurate.

3-03. STORMS AND FLOODS OF RECORD.

a. Little historical information is available concerning the magnitude of floods on Ballona Creek channel or its tributaries prior to 1938. During the flood of 1815, the Los Angeles River which flowed through what is now the business district overtopped its banks. These overflows traveled along the Ballona Creek channel, entering the ocean at what is now Marina Del Rey-Venice Beach. Ballona Creek continued to be part of the main channel of the Los Angeles River until 1825 when

another flood changed the course of the river to approximately its present alinement. Other major storms and floods in southern California occurred in 1862, 1867, and 1884, the greatest of which were those of January 1862. Heavy storms, some with significant flooding, have also occurred in Los Angeles and vicinity in 1886, 1889, 1890, 1891, 1905, 1906, 1911, 1914, 1916, 1921, 1926, 1927, 1934, 1938, 1939, 1941, 1943, 1952, 1954, 1956, 1957, 1958, 1962, 1965, 1966, 1967, 1969, 1973, 1974, and 1978. Brief descriptions of the more prominent storms and floods for which adequate rainfall and runoff information is available are included below.

b. Storm and Flood of 17-21 February 1914. After generally heavy rainfall in January 1914, another period of intense general winter rainfall hit southern California from 17-21 February as a series of three intensifying Pacific storms moved onto the coast from out of the west. Total storm precipitation in the western Los Angeles basin ranged from less than 5 inches along the southwest coast to an estimated 8-10 inches in the Santa Monica Mountains. 7.03 inches was measured at Los Angeles Civic Center, and more than 22 inches fell in the higher mountains of southern California. The heaviest rainfall generally occurred on 18 February, when 4.26 inches fell at Los Angeles Civic Center, including 1.49 inches in 1 hour. Flooding in the Los Angeles area was generally quite severe, and a peak flow on Ballona Creek about 500 feet below the wagon bridge on Higuera or Valley Road (drainage area approximately 71 sq. mi.) is given by the USGS (Water Supply Paper No. 447) as 6,480 cfs.

c. Storm and Flood of 27 February - 3 March 1938.

(1) The storm of 1938 was a general winter type and was one of the most severe on record in southern California. The storm consisted of a series of three individual disturbances which originated over the low-latitude north Pacific Ocean near Hawaii and moved eastward into southern California, spreading heavy precipitation across the coastal and mountain areas. Total storm precipitation in the Ballona Creek basin ranged from close to 8 inches along the coast near the mouth of the creek to around 15 inches in the Santa Monica Mountains. A 5-day total of 11.06 inches fell at Los Angeles Civic Center, while 11.90 inches fell at Beverly Hills City Hall; 12.53 inches was recorded at the Bel Air Hotel. More than 30 inches of precipitation was measured at several stations in the San Gabriel Mountains during the 5-day period.

(2) The first two disturbances of this storm passed on 27 and 28 February, respectively. After a lull in the rainfall on 1 March, the third, and most intense, disturbance crossed southern California during midday on 2 March, resulting in the highest recorded rainfall rates for a 4 to 8 hour period at a number of Los Angeles County stations. Los Angeles Civic Center, Beverly Hills City Hall, and the Bel Air Hotel measured maximum 6-clock-hour amounts of 3.37, 4.07, and 3.65 inches,

respectively - all on 2 March. These same stations recorded 6.28, 6.27, and 6.76 inches, respectively for 24-clock-hour periods ending on 2 March.

(3) Because of the thorough soaking of the ground by the first two phases of the storm, conditions for runoff were very favorable at the time of the high rainfall intensities of the storm's third phase on 2 March. As a result, flooding was severe in many areas, with the Los Angeles River and many other streams experiencing their greatest flows of record. On Ballona Creek at Sawtelle Boulevard, the maximum 1-day runoff volume was 7,330 acre-feet, the greatest on record, and the peak flow was estimated as 19,000 cfs on 2 March. Had this storm occurred under present conditions, it is estimated that the peak flow would have approached 25,000 cfs.

d. Storm and Flood of 21-23 January 1943. The general winter storms of 21-23 January 1943 resulted from the combination of a warm Pacific cyclone moving eastward from near Hawaii and a cold storm moving down the coast from British Columbia. Intense rain, with very strong winds, occurred primarily on 22 January, especially during the early hours and again during the late hours of the day. Rainfall was highly orographic, with some mountain stations receiving their greatest amounts of record for durations of 24 to 36 hours. This included the State of California 24-hour record of 26.12 inches, set on 22 January at Hoegge's, in the San Gabriel Mountains near Mt. Wilson. Total 3-day precipitation in the Ballona Creek drainage area ranged from less than 5 inches along the coast to more than 15 inches in the Santa Monica Mountains. Maximum 6-clock-hour rainfall amounts (all for periods ending on 22 January) included, respectively: 1.52 and 3.94 inches, Los Angeles Civic Center (catch believed to have possibly been deficient); 1.95 and 5.11 inches, Los Angeles - 6th and Main Streets; 5.40 inches for 24 hours, Los Angeles - Ducommun Street (6-hour amount not available); 1.17 and 3.25 inches, Baldwin Hills - Standard Oil Field Office; 1.78 and 5.13 inches, Hancock Park; 5.25 inches for 24 hours (6-hour amount not available), Beverly Hills City Hall; 3.30 and 7.33 inches, Bel Air Hotel; and 3.77 and 9.90 inches, Upper Franklin Canyon. Although the storm was quite severe, flooding was not generally extreme because of unusually dry antecedent conditions during the month before the storm began. The recorded peak discharge on Ballona Creek at Sawtelle Boulevard was 13,210 cfs on 22 January.

e. Storm and Flood of 3-4 March 1943. The local storm that occurred between 2200 hours on 3 March and 0100 hours on 4 March 1943 was part of a 3-day general storm which resulted from the slow eastward movement across southern California of a low-latitude north Pacific cyclone that had originated near Hawaii. Beginning on the morning of 3 March and lasting through much of 4 March, steady rainfall associated with the general storm provided abundant antecedent moisture; by the time of the local cloudburst, ground conditions were favorable for runoff. The intense local storm apparently began over the southern part

of the City of Los Angeles and moved northeastward to the San Gabriel Mountains. The maximum 3-hour precipitation at the Sierra Madre-Carter gage was 3.32 inches. Isohyets of this 3-hour cloudburst are shown on plate 8. Also included on plate 8 is a tabulation of 15-minute increments of precipitation at other stations. Runoff was moderately heavy from local areas where high precipitation intensities occurred. However, no quantitative measurements of runoff are available from the immediate vicinity of Sierra Madre, where the storm was centered. A peak discharge of 960 cfs was recorded for a 2.5-square-mile drainage area of the Broadway storm drain in Pasadena. The peak discharge on Ballona Creek at Curson Avenue was 5,300 cfs. Although the storm center occurred a number of miles from the Ballona Creek basin, this intense local rainfall cell serves as an illustration of the type of storm which can occur in the region.

f. Storm and Flood of 21 November 1967.

(1) The intense local storm which occurred over large portion of the Ballona Creek drainage during the evening hours of 21 November 1967 was part of a 3-day general storm of 19-21 November which developed as a cold low dropped down the west coast of the United States and combined with a low drifting eastward from the subtropical Pacific northeast of Hawaii, resulting in a moderately intense stationary cyclone southwest of southern California. Large quantities of warm moist air were pumped into Los Angeles and vicinity during the 3 days, with several major outbreaks of heavy thunderstorms recorded. Total 3-day precipitation in the Ballona Creek drainage exhibited a rather unusual distribution, largely because of the occurrence of the localized thunderstorms. The smallest values, less than 5 inches, occurred along the foothills of the Santa Monica Mountains west of the San Diego Freeway. The greatest storm totals, more than 10 inches, occurred just north of the Baldwin Hills east of Culver City.

(2) A heavy thunderstorm during the early morning hours of 19 November dropped a record 1.87 inches in 1 hour and 2.07 inches in 2 hours at Los Angeles - Ducommun Street (the adjacent Los Angeles Civic Center gage recorded 1.77 inches in 1 clock-hour and 2.11 inches in 2 clock-hours). Since this thunderstorm was the first rainfall of the 1967-1968 season, ground conditions were not favorable for heavy runoff, and no extensive flooding was reported. Showers continued through much of 19 and 20 November, some locally and briefly heavy. During the early morning of 21 November a general rainfall spread across the region, along with embedded very heavy showers. Los Angeles International Airport recorded 1.46 inches in 2 clock-hours during this period. Rainfall tapered off during the early afternoon of 21 November to partly cloudy skies.

(3) Shortly after sunset of 21 November an area of thunderstorms developed in the south and southwest of the Los Angeles basin and moved into the Ballona Creek region, rapidly building and intensifying. Heavy

rain spread irregularly northward across the southwestern portions of the Ballona Creek drainage area from around 1900 until shortly before midnight. Rainfall gages at the Hillcrest Country Club and the City Hall at Culver City recorded the most intense rainfall of this storm, approximately 0.80 inches per 15 minutes, 2.4 inches per hour, 3.7 inches per 3 hours, and 4.0+ inches per 3.5 hours. For the basin, isohyets of the maximum 15 minutes, and the storm are shown on plates 9 and 10. These rainfall values compare favorably to the transposed March 1943 isohyets (standard project storm). Because of the heavy antecedent rainfall of the preceeding 2 days, ground conditions in the Los Angeles basin were favorable for runoff by the time of the 21 November evening cloudburst. This storm produced the largest recorded peak flow at the Ballona Creek above Sawtelle Boulevard gage of 32,500 cfs on 21 November. Had the storm been critically centered over the watershed, it is estimated that a peak discharge approaching 40,000 cfs would have resulted.

g. Storms and Floods of 18-26 January 1969.

(1) In late January 1969 a series of unusually intense low-latitude Pacific storms moved into southern California from out of the southwest, bringing exceptional quantities of equatorial moisture into the region. There were four primary storm bands, each associated with a cold or occluded front, which passed across southern California during the 9-day siege, plus several minor impulses. Precipitation occurred primarily in two major phases: from the afternoon of 18 January to the morning of 22 January, and from the evening of 23 January through the afternoon of 26 January. The first two primary rain bands passed during the first phase crossing the Ballona Creek drainage basin during the late evening of 19 January and the early morning of 21 January, respectively. The last two bands passed during the second phase-near sunrise of 25 January and during this afternoon of 26 January.

(2) Total precipitation over the Ballona Creek watershed for the 9 days ranged from just over 10 inches in the Mar Vista-Culver City area to nearly 25 inches near the crest of the Santa Monica Mountains at the northwest corner of the basin. Los Angeles - Ducommun Street measured a total of 13.31 inches, while the Bel Air Hotel recorded 18.21 inches. In the higher San Gabriel Mountains, more than 50 inches of precipitation was recorded at Mt. Baldy. It has been estimated by Los Angeles County Flood Control District that the exceedence interval of the total 9-day rainfall in the central Los Angeles area is greater than 150 years.

(3) Very nearly half of the total precipitation fell during each of the two major storm passes. The greatest 24-hour storm totals occurred in most areas during the period ending on the afternoon of 25 January (the third of the four major storm bands), with amounts in the Ballona Creek drainage ranging from less than 3 inches south and west of the Baldwin Hills to more than 8 inches over the higher Santa Monica

Mountains. A few stations near the southwestern coastal portions of the Los Angeles basin, however, experienced the greatest 24-hour amounts during the first storm phase, mostly in conjunction with the first rainfall band.

(4) Although short-duration precipitation intensities were generally somewhat higher in the lower-elevation portions of the Los Angeles basin during the first rain band than during the second band, especially over areas bordering the southern and western edges of the Ballona Creek drainage basin, runoff volumes and peak flows in the Ballona Creek system were generally higher from the third band of precipitation than from any of the others. This was largely because the ground conditions had become nearly saturated by the time of the third rainfall band. A peak flow 17,000 cfs was recorded at the Ballona Creek above Sawtelle Boulevard gaging station on 25 January.

h. Storm and Flood of 3-4 December 1974. During the night of 3 December and the early morning of 4 December 1974, a cold front from a Pacific cyclone moved across southern California from out of the west, causing a rather brief but intense general winter storm over much of the region. Total precipitation over the Ballona Creek drainage ranged from 2 to 2.5 inches over the southern half to around 5 inches in the Santa Monica Mountains. Very heavy rain fell over portions of Los Angeles and Orange Counties to the southeast of the Ballona Creek drainage basin. The heaviest precipitation rates in and near the Ballona Creek drainage included .86 inches in 1 hour and 1.35 inches in 3 hours at Los Angeles International Airport, 1.29 inches in 1 hour and 2.72 inches in 3 hours at Upper Stone Canyon, and 1.30 inches in 1 hour and 1.90 inches in 3 hours at Los Angeles - 96th and Central-all during the early hours of 4 December. Streamflow was generally high throughout the southern portions of Los Angeles and Orange Counties. The estimated peak on Ballona Creek at Sawtelle Boulevard was 20,560 cfs on 4 December.

i. Storms and Floods of 5-13 February and 27 February - 5 March 1978. The intense storms of early February and early March 1978 were the climax of an unusually rainfall season that began in late December 1977 and continued into April 1978. The entire winter was characterized by a persistent series of warm, subtropical Pacific storms that moved into California from out of the west or southwest. Following more than double the normal monthly precipitation in December and two to three times the normal precipitation in January over much of southern California, many stations recorded three to four times normal rain in February and again in March. Many streams, including Ballona Creek and its tributaries, experienced unusually high runoff on a number of occasions during 1977-1978, the heaviest of which occurred on 10 February, 1 March, and 4 March.

(1) During early February 1978, periods of heavy rainfall occurred on 5, 7, 8-9, 10 and 12 February, the heaviest of which was that of early 10 February, which developed as an intense squall line moved

across southern California from the west. Total precipitation over the Ballona Creek drainage for the period 5-13 February ranged from around 6 inches in parts of Inglewood and Culver City to more than 12 inches near the crest of the Santa Monica Mountains. During the intense 10 February squall, rainfall intensities exceeded 1 inch per hour for short durations at many locations. The heaviest measured short-duration amounts in the Ballona Creek drainage occurred at Beverly Hills City Hall, where 0.76 inches in 10 minutes, 0.95 in 15 minutes, 1.38 in 30 minutes, and 1.61 in 1 hour were recorded, all between 0018 and 0118 hours 10 February. Maximum 30-minute and 1-hour amounts of 0.9 and 1.4 inches, respectively were recorded at the Hancock Park station, while figures for corresponding durations of 0.8 and 1.1 inches were measured at the Bel Air Hotel. The estimated peak discharge of 27,960 on Ballona Creek above Sawtelle Blvd. (Ballona Creek near Culver City), measured early 10 February by the Los Angeles County Flood Control District, was the second greatest flow of record. On the Sawtelle-Westwood tributary to Ballona Creek, the early 10 February estimated peak discharge of 11,700 cfs, measured above the Culver Blvd. by Los Angeles County Flood Control District, is the greatest of record.

(2) During the 27 February - 5 March 1978 storm period, major bursts of rain occurred on 28 February and on 1, 2, and 4 March. The 4 March period was generally the heaviest, although the most intense short-duration burst occurred on 1 March at some stations. Each storm of this series developed in a low pressure zone southwest of southern California and moved onshore, laden with moist, unstable tropical air. Total precipitation in the Ballona Creek drainage between 27 February and 5 March ranged from 7-8 inches in the Inglewood-Culver City area to more than 15 inches atop the Santa Monica Mountains. During the early hours of 1 March the Bel Air Hotel recorded 0.8 inches in 30 minutes and 1.2 inches in 1 hour, while Los Angeles International Airport measured 1.01 inches during the hour ending at 0200. Other maximum hourly amounts included 0.8 inches at Inglewood Fire Station, 0.73 inches at Beverly Hills City Hall, 0.6 inches at Hancock Park, and 0.59 inches at Los Angeles Civic Center. The estimated peak discharge on the Sawtelle-Westwood tributary above Culver Blvd. of 1 March was 9,050 cfs--second only to 11,700 cfs value of 10 February 1978 as the greatest on record. During the morning of 4 March the Inglewood Fire Station recorded 1.0 inches in 1 hour and 1.9 inches in 3 hours. Other 3-hour amounts include 1.6 inches at Hancock Park, 1.41 inches at Beverly Hills City Hall, 1.4 inches to Bel Air Hotel, and 0.93 inches at Los Angeles Civic Center. The estimated peak discharge on Ballona Creek above Sawtelle Blvd. (near Culver City) for the storm period was 17,930 cfs on 4 March.

IV. SYNTHESIS OF STANDARD PROJECT FLOOD

4-01. GENERAL. The standard project flood (SPF) represents the flood that would result from the most severe combination of meteorologic and hydrologic conditions considered reasonably characteristic of the region. It normally is larger than any past recorded flood in the area, and it can be expected to be exceeded only on rare occasions. It thus constitutes a standard of design that will provide a high degree of flood protection.

4-02. STANDARD PROJECT STORM. The most severe storm that could reasonably be expected to occur over the study area was determined to be a high intensity, short duration local storm equivalent to the storm of 3-4 March 1943 which centered in the San Gabriel Mountains near Los Angeles. Rainfall amounts and intensity patterns were taken, unaltered, from the report "Generalized Standard Project Rainflood Criteria for Southern California Coastal Streams," dated March 1967 and prepared by Hydrologic Engineering Center.

(1) The relative magnitude of local storms of record that have occurred in southern California is presented to illustrate the severity of the March 1943 local storm. All major local storms of record were considered under the assumption that the influence of topography on the magnitude of local storms is minor. The March 1943 storm occurred in an area with a large number of precipitation gages and is, therefore, one of the best defined storms of the group. The relative severity of this storm can be evaluated by comparing data on that storm with data on heavy short-time precipitation that occurred during other local storms in the southern California region.

(2) Intensity-duration curves for the largest recorded point precipitation of local storms in southern California and area-depth curves for storms of this group for which the area distribution of precipitation was fairly well defined are shown on plate 11. The curves clearly indicate that the magnitude of the March 1943 local storm generally exceeded the magnitude of most other major recorded local storms in the southern California coastal region, although some point-precipitation intensities for the 1943 storm were not maximum of record.

(3) Intensity duration and depth area curves for the March 43 storm, "as it occurred", transposed over the Ballona Creek watershed and several other severe storms which occurred over the Ballona Creek watershed are shown on plate 12.

4-03. DETERMINATION OF RAINFALL-RUNOFF RELATIONSHIPS.

a. Flood Reconstitutions.

(1) General. Reconstitution of 12 observed flood events in the Ballona Creek and Sawtelle-Westwood basins were accomplished to verify existing rainfall-runoff relationships used in computing hypothetical

flood hydrographs in urban watersheds. The Los Angeles District Flood Hydrograph Package (LADFHP) was used to perform the reconstitutions. This program incorporates the HEC loss rate function and allows subdivision of the watershed for reconstitution of storm events where rainfall is spacially uneven. Table 10 presents a summary of best-fit unit hydrograph and rainfall loss rate parameters determined for each reconstitution. These parameters are comparable to values used in previous studies in the Los Angeles area. The reconstitutions are presented graphically on plates 13 through 24.

(2) Large discharges have generally been produced by spacially uneven rainfall, e.g., Nov. 21, 1967 and Dec. 4, 1974. Using one subarea introduces large errors which can be avoided by subdividing the watershed. The Ballona Creek watershed was subdivided into four subareas, the Sawtelle-Westwood watershed was subdivided into nine subareas as shown on plate 1. Likewise the abundance of recording precipitation stations located in and near the watersheds allowed definition of subarea precipitation.

(3) The loss rate variables, basin "n" values and S-graphs were determined by trial and error. Subarea hydrographs were combined and routed in the conventional manner. Routing coefficients in the improved channel were determined from the initial reconstitution. Subsequent reconstitutions refined or "optimized" the initial set of coefficients. These "best fit" routing coefficients are shown in table 11.

(4) For each reconstitution, each subarea precipitation pattern was derived from one or more stations. Throughout the storms, each station provided a constant percent of the total subarea precipitation. The error in this procedure is acknowledged but considered smaller than the error resulting from estimating a variable percent contribution of each station as the storm moves over the subject area. This error can be seen in some reconstitutions of longer duration when a reconstituted limb leads a recorded limb, then at a later time lags the recorded limb.

b. Unit Hydrographs.

(1) LADFHP is a computer program which uses the Los Angeles District unit hydrograph method to compute flood hydrographs. The District's unit hydrographs procedure utilizes the S-graph which is the time distribution of runoff as a function of basin lag time. Lag time is defined as the time in hours for 50 percent of the total volume of runoff of the unit hydrograph to occur. The basin lag time can be approximated by use of the lag relationship presented on plate 25. The basin "n" value is a variable in the equation for lag time which permits adjustment of lag time depending on type of ground cover and surface characteristics affecting basin response to effective rainfall. Subarea unit hydrographs parameters used in the initial Ballona Creek channel

study are presented in table 12, while the modified subarea unit hydrograph parameters used for the later Sawtelle-Westwood study are shown in table 13.

(2) The S-graphs used to derive the synthetic unit hydrographs are shown on plate 26. These S-graphs, the result of previous studies performed on similar basins in the Los Angeles area, were found to give suitable reconstitutions (plates 13 through 24).

(3) Subarea "n" values derived from the reconstituted flood hydrographs for the Ballona Creek and Sawtelle-Westwood basins and "n" values from reconstitutions in similar watersheds in the Los Angeles region were used as a guide to establish standard project flood "n" values for the study areas. Adjustments, based on judgments, were made to consider the influence of various factors, including storm drains, which affect the lag time of the watershed. Basin "n" values for subareas under present and future conditions are given in tables 12 and 13.

c. Rainfall Loss Rate Function. The selected HEC loss rate parameters were based on the reconstitution of flood events in the Ballona Creek and Sawtelle-Westwood watersheds and other basins with similar geomorphological characteristics. The "Best Fit" Loss rate parameters for many of the reconstituted flood events shown in table 10 support the use of minimum constant loss rate for a rare event such as the standard project flood. The parameters used in this study for standard project flood computations are as follows: STRKR = 0.20, RTIOL = 1.0, ERAIN = 0. The HEC loss rate function accounts for urbanization by reducing the effective loss rate in direct proportion to the percent impervious cover of the watershed.

d. Baseflow and Snowmelt. Baseflow was considered negligible for this study. Snowmelt is not a contributing factor to runoff in this basin.

4-04. FLOOD ROUTING.

a. The complexity of the Ballona Creek and Sawtelle-Westwood watersheds required use of several different routing methods. Flood routing computations were made in accordance with "Routing of Floods Through River Channels, EM 1110-2-1408, Corps of Engineers, 1 March 1960."

b. The successive average-lag (Tatum) method was used to route flows in the existing concrete-lined Ballona Creek channel. This method, considered appropriate with this type of channel, was used because of the ease with which the short-travel time in the numerous short reaches can be handled. Velocities, on which travel times were based, were obtained from previously computed water surface profile computations. Routing coefficients are shown in table 11.

c. The Muskingum routing technique was used to route overland and overbank flow in the Ballona Creek watershed and to route overland and channel flows in the Sawtelle-Westwood watershed. Flood wave travel time in a reach, which approximates the Muskingum coefficient K was determined by dividing reach length by average-peak flow velocity. Manning's formula for normal depth and an appropriate cross section were used to compute the average peak flow velocity for the reach. Cross sections were determined from available topographic maps and field inspections. Muskingum X values were estimated according to the relative importance of storage and inflow. The flat sloped, wide overland flow reaches required X values close to zero. Table 11 also lists routing coefficients in the Sawtelle-Westwood watershed.

d. The Modified Puls routing procedure was used to determine the impact on channel flow of a "low" bridge (as defined in paragraph 2-07d). Elevation-storage relationships were determined from as-built channel drawings, available near-channel topography, and field inspection. Rating curves for "outflow" were developed using standard hydraulic principles.

4-05. COMPUTATION OF STANDARD PROJECT FLOOD.

a. Stream System Analysis.

(1) The stream system analysis approach to computation of design floods involves division of a study area in subareas which are homogeneous with respect to hydrologic and meteorologic factors, and routing and combining of the flood hydrographs generated from each subarea to determine the design flood at a desired concentration point. Subdividing a watershed permits more accurate modeling of the runoff process, as variations in topography and urbanization, as well as changes in channel characteristics, may be incorporated into the hydrologic description of the basin.

(a) In the Ballona Creek watershed the subareas used in the reconstitutions were adequate to describe the runoff process. However, in the Sawtelle-Westwood watershed further division of the watershed was necessary to more accurately define the runoff process. Table 13 shows these modified unit hydrograph parameters.

(2) Standard project floods were computed by centering the standard project storm in the most critical flood producing manner. Application of the rainfall loss rate function described previously to standard project precipitation enables determination of the rainfall excess. The rainfall excess is then applied to the subarea unit hydrograph to produce the subarea flood hydrograph. Combining and routing of subarea flood hydrographs to the desired concentration point completes the computation of a standard project flood. In making standard project flood determinations, the small water supply reservoirs in the basin were assumed to be full to spillway crest at the beginning of the standard project storm.

b. Standard Project Flood Peak Discharges. Standard project flood peak discharges, computed as described in foregoing paragraphs, are presented for present and future (ultimate) conditions, for restricted channel and bridge conditons and for future unrestricted conditions. Plates 27 through 29 and table 14 give values for each condition on Ballona Creek channel. Table 15 presents present and future, standard project flood peak discharges for Sawtelle-Westwood channel.

c. Adequacy of Standard Project Flood. The standard project flood is of a magnitude that would be exceeded only on rare occasions. As is often the case, the computed standard project flood is greater than the largest recorded event in the Ballona Creek watershed. The adequacy of the standard project flood estimates is indicated by a comparison with long-term streamflow records in the basin and with the enveloping curve of peak discharges for other coastal streams in southern California (pl. 30).

V. DISCHARGE FREQUENCY ANALYSIS

5-01. GENERAL.

a. Discharge frequency analysis in the Ballona Creek basin involved determination of peak discharge frequency values at selected locations: (1) along Ballona Creek channel, and (2) in the Sawtelle-Westwood watershed. These discharges represent present and future basins development with various combinations of present and proposed storm drain systems, channel and bridge conditions. These discharges are required to determine the adequacy of the existing channel and bridges and the feasibility of alternative plans for channel and bridge improvements.

5-02. BALLONA CREEK CHANNEL.

a. The continuous record extending from 1928 through 1978 at the Ballona Creek above Sawtelle Boulevard stream gage was the basis for the discharge-frequency analysis on Ballona Creek channel. Because of the constantly increasing urbanization in the watershed, the 51-year record reflects nonhomogeneous basin conditions. This is demonstrated by grouping the record into overlapping segments of time, mostly 10 years long, and computing the mean of the logarithms of the peak discharge recorded during each segment of time. For each segment of time, the average percent of impervious cover of the watershed was estimated by using topographic maps and population records. Plate 31 shows the percent of impervious cover plotted against the mean of the annual peak discharges for each time segment.

b. This plate shows that runoff has generally increased in Ballona Creek due to watershed development. This change in the watershed negates use of the entire record in the customary Log Pearson Type III discharge-frequency analysis recommended by the U.S. Water Resources Council

c. The period of record from 1951 through 1978 was used in a Log Pearson Type III (analytical) analysis. This period of record provided discharges from a relatively homogeneous basin (compared to the full record) and included a sufficient number of events to provide reliable discharge frequency relationships. Following the U.S. Water Resources Council's "Guidelines for Determining Flood Flow Frequencies", the analytical curve shown on Plate 32 was derived using a generalized skew coefficient of zero, and expected probability adjustments. The upper portion of the curve represents unrestricted channel conditions where all flow stays in the channel.

d. Derivation of the graphical curves shown on plate 32 was in part based on the data shown on plate 31. A review of this plate shows that the earlier events generally produced lower peaks than the later events. Had the earlier events occurred under 1978 basin conditions,

they would have been higher. Therefore, extending the curve on plate 31 yields a present mean of approximately 15,000 cfs (basin percent impervious cover = 53%) and a future mean (2078) of approximately 18,500 cfs (basin percent impervious cover = 75%). With the computed standard project flood peak discharges, present and future conditions, unrestricted flow = 50,000 and 57,000 cfs, respectively, only the standard project flood peak discharge for the period 1951-78 is unknown (see pl 32). Since the 1951-78 mean discharge is smaller than the present 1978 mean discharge, it is reasonable to assume the same relationship exists for the standard project flood peak discharges. Using estimated subarea percent impervious cover and "n" values for 1965 (halfway between 1951-78) a standard project flood peak discharge of approximately 46,000 cfs was computed. This discharge plotted on the analytical curve identifies the frequency of this standard project flood. The present (1978) and future (2078) discharge frequency curves were then drawn using their respective mean discharges, the standard project flood peak discharges, and the analytical curve as a guide for shape.

e. For this study, the SPF was derived by critically centering the maximum 3 hours of the March 1943, San Gabriel Mountains thunderstorms (standard project storm) over the Ballona Creek watershed. The National Weather Service (NOAA) rainfall statistics show the March 1943 storm transposed over Ballona Creek basin, has about 100-year return frequency for its maximum 3-hour and 1-hour intensities. Also, maximum 3-hour intensities of three recorded events on the Ballona Creek watershed, the March 1938, the November 1967, and the December 1974 storms were within 65 to 85 percent of that for the standard project storm. Recorded point rainfall for some events, in particular the November 1967 rainfall approached or exceeded in magnitude the maximum March 43 point rainfall for several time intervals. Although rainfall frequencies are poor indicators of runoff frequencies, the characteristics of the standard project storm appear to be those which could produce runoff with an exceedence interval of approximately 400 years.

f. All the discharge frequency curves previously discussed represent "unrestricted conditions" where all flow is conveyed by the Ballona Creek channel without overflowing. Discharges exceeding approximately 38,000 cfs overflow causing major alterations to the discharge frequency curve. (See pl. 7 for the conveyance capacities of the Ballona Creek channel.) Because of the high velocities in the Ballona Creek channel as compared to the low velocities of overbank flow, overflow lags behind and does not contribute significantly to the downstream peak discharges at the gage site. Discharge-frequency relationships along the entire length of the channel were derived by drawing parallel curves to the gaging station curves using the computed SPF's as a guide. Plates 33 through 35 and table 14 present 100 year peak discharges, present conditions restricted flow, and future conditions, restricted and unrestricted flow, along Ballona Creek channel.

5-03. SAWTELLE-WESTWOOD WATERSHED.

a. The rationale used to develop the discharge frequency curves from the record of the gage located on Ballona Creek channel near Culver City was also used to develop a discharge frequency curve from the record of the gage located on Sawtelle-Westwood channel above Culver Blvd. Plate 36 shows the percent of impervious cover plotted against the mean of the annual peak discharges for each time segment. The discharge frequency curves shown on plate 37 represents runoff in a predominately urbanized watershed. For concentration points in the upper reaches, areas with little urbanization, the Dume Creek at Pacific Coast Highway gage record was used.

b. The Dume Creek watershed located approximately 20 miles up the coast has runoff characteristics somewhat similar to the upper reaches of the Sawtelle-Westwood watershed. This watershed is 8.8 square miles at the gaging station has a low percent impervious cover, and a station record with 7 years of zero flood flows. The method of combining probabilities described in the Water Resources Council's Bulletin 17A was used for including these zero values in the computation of a frequency curve. Plate 38 shows the initial curve based on the statistics of non-zero flows with the exceedance probabilities adjusted by the ratio of the number of years of non-zero flows to total years of record. It also shows the final adopted curve adjusted to Log-Pearson Type III distribution using a regional skew of -0.20. A future conditions curve was not derived because the increase in runoff future over present was small. Since only 100 year and SPF discharges were necessary future conditions 100 year discharges were derived using the present conditons 100 year to SPF ratio.

c. Discharge frequency relationships in the lower reaches were derived by drawing parallel curves to the Sawtelle-Westwood gaging station curve using SPF's as a guide. Discharge frequency relationships in the upper reaches were derived by drawing parallel curves to the Dume Creek curve using SPF's as a guide. Discharge frequency relationships in the middle reaches were derived by combining the two curves graphically on a percent impervious cover basis, e.g., the higher the percent impervious cover the closer the curve approaches the Sawtelle-Westwood curve. Table 15 lists SPF's and 100 year discharge at each concentration point.

Table 1
Storm Drain Capacities by Subarea
Ballona Creek Watershed

Subarea	Name or Number	LACFCD Design Q	Approximate Discharge with Channel Full (in cfs)	
			Present	When Completed
8	Sacatella	4615	4615	4615
	1102	3400	3400	3400
	Highland Ave. Relief	3000	0	3000
	57 and 93: Spur L	2575	2575	2575
	Spur M	2010	2010	2010
	Total	15600	12600	15600
7	494	435	435	435
	Thurman Avenue	200	200	200
	54	1970	1630	1630
	DDI-#11	4300	3560	3560
	La Cienega	300	300	300
	648-C	138	138	138
	Total	7343	6263	6263
6	53	2930	2730	2730
	84	3700	3570	3570
	Higuera St.	2040	2040	2040
	Higuera St. (Est.)	200	200	200
	Proposed 9406	3570	0	3430
	Total	12440	8540	11970
5	Benedict Canyon Channel (Corps channel)	12000	12000	12000
4	52	700	700	700
	424A	310	310	310
	425	220	220	220
	A & I #4	780	780	780
	2901	240	240	240
	Total	2250	2250	2250
3	Sepulveda Channel (Corps channel) (See next Table)	13000	13000	13000
2	504	270	270	270
	51	690	690	690
	504	550	550	550
	505	340	340	340
	Total	1850	1850	1850
1	Centinela Creek Channel (Corps channel)	8700	8700	8700

Notes: The inflow capacity of some drains is reduced as the water surface in the channel approaches the top of wall.

The Corps channel capacities do not include freeboard.

See plate 1 for subarea locations.

See plate 5 for stormdrain locations.

TABLE 2
Estimated Storm Drain Capacities by Subarea
Sawtelle-Westwood Watershed
(in cfs)

Subarea	Location	Design Q
1	Along Sepulveda Blvd: Mountain Gate	300
	1750' South of Brownfield	100
	Numerous Small Drains Along Sepulveda (Mulholland to Bel Terrace)	*
3	Sepulveda and Bellagio	*
	Sepulveda and Moraga	320
	Numerous Small Drains Along Sepulveda	
5	Sepulveda and Montana	110
	Numerous Small Drains Along Sepulveda	*
6	Upper Dry Canyon	906
	Dry Canyon U/S Sunset	326
7	Local Inflows along Veterans	Est 1000
9	Stone Cyn. Box under Sunset Blvd.	912
10	Local Inflows	0
11	Local Inflows Along Veterans	Est 100
	Gayley D/S Prkg Str	443
	(Enters 498 D/S Weyburn)	
	Total Cap 498	1140
	Local Inflows Along Sepulveda	100
	Santa Monica & Camden (East-West)	100+
	Santa Monica & Greenfield (North-South)	876
	Total (Santa Monica) = (1140 + 100 + 100+) + (876) = 2200 (1340 enters Corps Channel)	
13+	Local Inflows along Channel-City drains	Est 200
14	National & Coventry County-City 2 Lines:	
	Military (Midvale)	906
	Coventry	2464
	Sawtelle and Channel	320
	Butler and Channel	Est 150
	Total	Est 4000

Table 2 (Continued)

12	Beverly Glen Nr Montline Ln	Est 700
14	San Viciente & Barrington	212
15	Brookhaven (Drains Centinela & Bundy)	405
	Gateway	50
	Pearl St. (South of Fwy - Drains Westgate)	Est 500
	Local Inflows South of Fwy	Est 500
	Barrington @ Fwy	1270
	Total (1270 + 500 + 50 + 405 + 100) = 2300	

* Unknown Capacity

See plate 2 for subarea locations.

Table 3DEPARTMENT OF WATER AND POWER
WATER SUPPLY RESERVOIRS

Name	Drainage Area (Sq. Mi)	Capacity in Ac.Ft. at Spillway Crest	Date Completed
Silverlake	0.13	2324	1907
Ivanhoe	0.11	180	1906
Upper Hollywood	0.37	196	1933
Lower Hollywood	1.01	4034	1924
Upper Franklin	0.53	118	1914
Lower Franklin	1.24	1031	1916
Upper Stone	0.66	425	1954
Lower Stone	1.36	10372	1924

(Enlarged 1956)

See plates 1 and 2 for locations.

Table 4

COMPARISON OF DESIGN DISCHARGES ON BALLONA CREEK
(Discharges in cfs)

						Current Corps Study (1978)	
CP**	DA (SQ MI)	1935 Corps Study	1949 LACFCD+ Study	1954 Corps +	1968 LACFCD Restudy	SPF Present***	SPF Future****
		"Ultimate Q" (Based on LACFCD Q's)		Restudy (SPF's)		(Restricted channel flow)	(Unrestricted channel flow)
108	Burnside Ave.	25	7,950	11,950	23,000	23,000	28,000
1072	Fairfax Ave.	26	14,150	12,980	30,000	23,300	*18,000
107	Washington Blvd.	45	18,500	19,520	30,000	34,200	36,000
1062	National-Jefferson		30,000	28,730	38,500	40,000	39,000
106	D/S Higuera St.	70	30,000	28,700		47,600	45,000
D/S 105	Overland Ave.	85	40,500	36,000		57,500	50,000
	U/S Sepulveda Blvd.					57,500	50,000
1032	Sepulveda Blvd.	88				57,500	*38,000
U/S 103	Sepulveda Channel	91	40,000	35,700		57,500	*39,000
D/S 103	Sepulveda Channel	112	47,000	48,340	46,000	67,400	55,000
101	Centinela Creek	120	47,500	53,975	46,000	67,400	61,000
100	Ocean		46,000	49,500	46,000		68,000

+ REFERENCE: 1954 Hydrology Calculations.

* Restricted flow at bridge.

** Locations shown on Plate 1

*** Discharges shown on Plate 27

**** Discharges shown on Plate 29

TABLE 5

Summary of Climatological Data

Month	TEMPERATURE				PRECIPITATION		
	Mean Monthly Maximum	Mean Monthly Minimum	Record Highest	Record Lowest	Mean Monthly Inches	Maximum Monthly Inches	Minimum Monthly Inches
	Degrees Fahrenheit	Degrees Fahrenheit	Degrees Fahrenheit	Degrees Fahrenheit			
Los Angeles International Airport, California							
January	63.5	45.4	88	23	2.52	9.60	0
February	64.1	47.0	92	32	2.32	11.07	T
March	64.3	48.6	88	34	1.71	5.98	0
April	65.9	51.7	95	39	1.10	4.52	0
May	68.4	55.3	97	43	.08	.56	0
June	70.3	58.6	100	48	.03	.29	0
July	74.8	62.1	97	49	.01	.15	0
August	75.8	63.2	98	51	.02	.30	0
September	75.7	61.6	110	47	.07	4.39	0
October	72.9	57.5	106	41	.22	2.34	0
November	69.6	51.3	101	34	1.76	7.92	0
December	66.5	47.3	94	32	2.39	6.57	T

NOTE - Above data from NOAA Climatological Data.

Mean Values are based on NOAA Normals for period 1941 - 1970.

Extreme Values are based on data For Period 1936 - 1976.

Los Angeles Civic Center, California							
January	66.5	46.8	95	28	3.00	14.94	0
February	67.6	48.5	91	34	2.77	12.42	T
March	68.6	49.8	94	35	2.19	8.14	0
April	70.5	52.9	99	39	1.27	6.02	0
May	73.2	56.1	102	46	.13	1.43	0
June	76.5	59.5	106	50	.03	.32	0
July	82.9	63.5	103	54	0	.03	0
August	83.7	64.4	103	53	.04	.39	0
September	82.5	62.8	110	51	.17	2.82	0
October	78.0	58.7	104	41	.27	1.53	0
November	73.2	52.1	100	39	2.02	9.68	0
December	66.5	47.3	94	32	2.16	6.57	T

NOTE - Above data from NOAA Climatological Data. Mean values are based on NOAA Normals for period 1941-1970.
Extreme values are based on data for period 1941-1976.

Table 6
Precipitation Stations

Station Name	L.A.C.F.C.D. No.	Gage (Type)	Elev. (ft)	Latitude (deg.) (min.)		Longitude (deg.) (min.)		Yrs. of Record
1. Bel Air Hotel	10	SA	535	34	05	118	27	45
2. Beverly Hills City Hall	228	SA	255	34	04	118	24	48
3. Culver City	246	S	100	34	01	118	24	38
4. Griffith Park-Fern Dell	757	A	750	34	07	118	18	26
5. Griffith Park-Little Canyon	755	A	900	34	08	118	17	26
6. Griffith Park-Nursery	257	S	850	34	07	118	17	42
7. Hillcrest County Club-L.A.	462	S	185	34	03	118	24	33
8. Hollywood Dam	238	S	750	34	07	118	20	44
9. Inglewood Fire Sta.	116	SA	153	33	58	118	21	51
10. Los Angeles	213	SA	200	34	04	118	21	44
11. L.A. City College	355	SA	310	34	05	118	17	49
12. L.A.-Clark Memorial Library	278	S	203	34	02	118	19	43
13. L.A.-Ducommun St.	716	SA	306	34	03	118	14	101
14. L.A.-Echo Park and Lucretia	772	A	475	34	05	118	15	26
15. L.A.-McQueen	1039	S	225	34	04	118	19	22
16. L.A.-USC	482	S	208	34	01	118	17	31
17. L.A.-96th and Central	291	SA	121	33	57	118	15	43
18. Lower Franklin Canyon	794	S	585	34	06	118	25	25
19. Mount St. Mary's College	285	S	1025	34	05	118	29	43
20. Nichols Debris Basin	759	A	440	34	06	118	21	26
21. Santa Monica	634	S	94	34	01	118	29	46
22. Sawtelle	140	A	250	34	03	118	27	45
23. Sawtelle-Soldier's Home	119	S	345	34	03	118	27	77
24. Sepulveda Canyon-Bellazic Road	778	S	570	34	05	118	28	21
25. Silver Lake Reservoir	336	SA	445	34	06	118	16	43
26. Stone Canyon Reservoir	237	S	865	34	06	118	27	48
27. Upper Franklin Canyon Reservoir	11	SA	867	34	07	118	25	46
28. Upper Stone Canyon	762	A	943	34	07	118	27	26
29. Venice Fire Sta.	126	S	55	34	00	118	28	45
30. Westwood-UCLA	680	S	430	34	04	118	26	41

S Standard 8" - Diameter Non-recording Gage

A Automatic Recording Gage

SA Both Standard 8" - Diameter Gage and Automatic Recording Gage

TABLE 7

STREAM GAGING STATIONS

LACFLD Station Number	Name	Drainage Area (Sq. Mi.)	Period of Record
F 038C-R	Ballona Creek Above Sawtelle Boulevard	89	Ø8-10-67 to Present
F 038-R	Ballona Creek At Centinella Boulevard	111	Ø2-27-28 to 4-27-36
F 29B-R	Ballona Creek At Curson Avenue	26	Ø2-17-42 to 9-4-62
F 166-S	Ballona Creek at Jacob Street		12-21-31 to 5-20-37
F 282-R	Ballona Creek At Pacific Avenue		Ø8-9-40 to 8-1-62
F 038B-R	Ballona Creek At Sawtelle Boulevard	89	Ø5-14-36 to 8-10-67
F 294-R	Ballona Creek At Sepulveda Boulevard	89	Ø4-14-48 to 4-29-53
F 156-S	Ballona Creek East Branch Below Adams Street		10-6-32 to 7-19-34
F 293-R	Ballona Creek 800 Feet Below Culver Blvd.		Ø4-15-48 to 4-29-53
F 301-R	Sawtelle-Westwood Channel Above Culver Blvd.	23	Ø1-22-51 to Present
F 185-R	Sepulveda CK (Sawtelle-Westwood Ch) at Charnock Rd.	23	Ø9-15-32 to Ø5-29-50

Table 8

Peak Discharges
Ballona Creek Above Sawtelle Boulevard

SEASON	MONTH	DAY	Peak Flow C.F.S.
1914	2	18-21	6480 (Est.)
1927-28	5	8	1100
1928-29	3	10	4990
1929-30	1	11	4460
1930-31	4	26	6280
1931-32	12	28	6130
1932-33	1	19	7000
1933-34	1	1	11300
1934-35	4	8	11200
1935-36	2	12	8070
1936-37	12	30	8940
1937-38	3	2	19000
1938-39	12	17	9900
1939-40	2	3	9730
1940-41	12	23	17300
1941-42	12	10	7500
1942-43	1	22	13200
1943-44	2	22	8800
1944-45	11	11	9380
1945-46	12	22	7750
1946-47	12	25	9630
1947-48	3	24	12700
1948-49	2	7	5740
1949-50	2	6	7670
1950-51	1	10	5460
1951-52	1	16	12800
1952-53	11	15	11500
1953-54	2	13	18900
1954-55	1	18	9370
1955-56	1	26	18700
1956-57	2	23	13900
1957-58	2	19	15200
1958-59	1	6	8170
1959-60	1	11	12500
1960-61	11	5	7700
1961-62	2	19	2900
1962-63	3	16	12100
1963-64	1	22	6420
1964-65	4	9	17600
1965-66	11	22	18000
1966-67	11	7	13900
1967-68	11	21	32500

Table 8 (Continued)

Peak Discharges
Ballona Creek Above Sawtelle Boulevard

SEASON	MONTH	DAY	Peak Flow C.F.S.
1968-69	1	25	17000
1969-70	2	28	7900
1970-71	11	29	14600
1971-72	12	24	11100
1972-73	1	16	17600
1973-74	1	7	11000
1974-75	12	4	20560
1975-76	9	10	12940
1976-77	10	23	10172 (Est.)
1977-78	2	10	27960 (Est.)

Table 9

**Peak Discharges
Sawtelle-Westwood Channel**

Sepulveda Creek at Charnock Rd.

SEASON	MONTH	DAY	Peak Flow C.F.S.
1932-33	1	29	834
1933-34	12	31	1150
1934-35	4	8	1560
1935-36	2	12	1810
1936-37	2	14	1980
1937-38	3	2	3100
1938-39	9	25	1076
1939-40	2	2	1890
1940-41	12	23	3010
1941-42	12	28	2200
1942-43	1	22	2220
1943-44	2	23	1940
1944-45	11	11	1460
1945-46	12	22	1900
1946-47	11	13	2100
1947-48	3	24	1710
1948-49	2	7	1530
1949-50	2	6	1470

Sawtelle-Westwood Channel above Culver Boulevard

1951-52A	1	16	4240
1952-53	11	11	3150
1953-54	2	13	4150
1954-55	1	10	2140
1955-56	1	26	3130
1956-57	2	23	4170
1957-58	2	25	2970
1958-59	2	8	2380
1959-60	4	27	3310
1960-61	11	5	2950
1961-62	2	12	7250
1962-63	3	28	2590
1963-64	1	21	3500
1964-65	4	9	4240
1965-66	11	22	4140
1966-67	1	22	3610
1967-68	11	21	6560
1968-69	2	6	6840
1969-70	11	6	2300

Table 9 (Continued)

Peak Discharges
Sawtelle-Westwood Channel

Sawtelle-Westwood Channel above Culver Boulevard (Continued)

SEASON	MONTH	DAY	Peak Flow C.F.S.
1970-71	11	29	6890
1971-72	12	27	5726
1972-73	1	6	4970
1973-74	1	7	3390
1974-75	12	4	7700
1975-76	2	6	2150
1976-77	5	8	2820
1977-78	2	10	11700 (Est.)

A = Record began January 22, 1951. Prior records at station F185-R Sepulveda Creek at Charnock Road, for the periods September 15, 1932 to March 3, 1937; August 11, 1937 to March 2, 1938; and July 7, 1938 to May 29, 1950. From May 29, 1950 to January 22, 1951, no record was obtained due to channel construction.

Table 10

"Best Fit" Unithydrograph Parameters

Ballona Creek

Date of Flood	Subareas Included	Basin "n"	Estimated Percent	Loss Rate		Antecedent Rainfall				Total Storm Rainfall (In Inches)		
			Impervious Cover	STRKR*	RTIOL**	(In Inches)						
Mar. 2, 38	5	.030	10	.3	2.0	Feb. 27	Feb. 28	Mar. 1	6.13			
	6	.035	25	.3	2.0			(0000-2100)				
	7	.035	15	.3	2.0	1.5	3.0	0				
	8	.025	30	.3	2.0							
Apr. 9, 65	5	.021	40	.4	1.0	Apr 1-4	5	6-8	9	1.34		
	6	.025	60	.4	1.0				(0-1300)			
	7	.019	50	.4	1.0	2.6	0	1.7	0			
	8	.017	60	.4	1.0							
Jan. 25, 69	5	.021	40	.3	3.0	Jan 15-17	18	19	20	21	21-23	4.44
	6	.025	60	.3	3.0						(0-800) (0800-2000)	
	7	.019	50	.3	3.0							
	8	.017	60	.3	3.0	0	.75	1.5	3.0	0.7	0	
Feb. 23, 69	5	.025	40	.4	1.0+	Feb 18	19	20	21	22-23	1.65	
	6	.029	60	.4	1.0+					(0-0800)		
	7	.023	50	.4	1.0+							
	8	.021	60	.4	1.0+	.25	.30	0	0.5	0		
Dec. 4, 74	5	.023	40	.95	1.0	Over a month prior to 1800, 12/3					2.88	
	6	.027	60	.95	1.0	0						
	7	.021	50	.95	1.0							
	8	.019	60	.95	1.0							
Nov. 21, 67	5	.021	40	.2	1.5	Nov 19	20	21			1.85 0.9 2.85	
	6	.025	60	.3	2.0	(0-1300)						
	7	.019	50	.2	1.0							
	8	.017	60	.4	2.0							

Table 10

**"Best Fit" Unithydrograph Parameters
Sawtelle Westwood**

Date of Flood	Subareas Included	Basin "n"	Estimated Percent Impervious Cover	Loss Rate		Antecedent Rainfall						Total Storm Rainfall (In Inches)
				STRKR*	RTIOL**	(In Inches)						
Apr. 9, 65	31	.015	50	.60	2.0	Apr 4/1	2	3-4	5-6	7-8	9	1.41
	32	.015	45	.60	2.0						(0-1300)	
	33	.025	35	.60	2.0							
	34	.025	15	.60	2.0	1.1	.4	1.9	0	1.5	0	
	35	.025	10	.60	2.0							
	36	.030	15	.60	2.0							
	37	.020	20	.60	2.0							
	38	.025	5	.60	2.0							
	39	.025	5	.60	2.0							
Nov. 21, 67	31	.015	50	.55	2.0	Nov 19	20	21		21		1.71
	32	.015	45	.55	2.0						(0-1300) (1300-1900)	
	33	.025	35	.55	2.0							
	34	.025	15	.55	2.0	1.1	8	2.9		0		
	35	.025	10	.55	2.0							
	36	.030	15	.55	2.0							
	37	.020	20	.55	2.0							
	38	.025	5	.55	2.0							
	39	.025	5	.55	2.0							
Jan. 25, 69	31	.020	50	.40	2.0	Jan 15-17	18-21	22		22-23		6.07
	32	.020	45	.40	2.0						(0-0800) (0800-2000)	
	33	.030	35	.40	2.0							
	34	.030	15	.40	2.0	0	8.8	.4		0		
	35	.030	10	.40	2.0							
	36	.035	15	.40	2.0							
	37	.025	20	.40	2.0							
	38	.030	5	.40	2.0							
	39	.030	5	.40	2.0							

Late
1 Period +

Late
1 Period +

Table 10

**"Best Fit" Unithydrograph Parameters
Sawtelle Westwood**

Date of Flood	Subareas Included	Basin "n"	Estimated Percent Impervious Cover	Loss Rate		Antecedent Rainfall				Total Storm Rainfall (In Inches)	
				STRKR*	RTIOL**	(In Inches)					
Feb. 6, 69	31	.015	50	.6	1.5	Jan 29-Feb 4	5	5		1.51	
	32	.015	45	.6	1.5			(0-0800)	(0800-2400)		
	33	.015	35	.6	1.5	0	.40	0			
	34	.025	15	.6	1.5						
	35	.025	10	.6	1.5						
	36	.030	15	.6	1.5						
	37	.020	20	.6	1.5						
	38	.025	5	.6	1.5						
	39	.025	5	.6	1.5						
Feb. 23, 69	31	.015	50	.2	2.0	Feb 18	19	20	21	22-23	1.92
	32	.015	45	.2	2.0					(0-0800)	
	33	.025	35	.2	2.0						
	34	.025	15	.2	2.0						
	35	.025	10	.2	2.0	.25	.30	0	.5	0	
	36	.030	15	.2	2.0						
	37	.020	20	.2	2.0						
	38	.025	5	.2	2.0						
	39	.025	5	.2	2.0						
Dec. 4, 74	31	.015	50	.75	1.0	Over a Month Prior to 1800					4.10
	32	.015	45	.75	1.0	12/3					
	33	.025	35	.75	1.0						
	34	.025	15	.75	1.0						
	35	.025	10	.75	1.0			0			
	36	.030	15	.75	1.0						
	37	.020	20	.75	1.0						
	38	.025	5	.75	1.0						
	39	.025	5	.75	1.0						

* STRKR Starting Value of Loss Coefficient on Exponential Recession Curve for Rain Losses.

** RTIOL Ratio of Rain Loss Coefficient on Exponential Loss Curve to that corresponding to 10 inches more of Accumulated Loss.

Table 11
ROUTING COEFFICIENTS

Tatum Routing Coefficients
Ballona Creek Channel

Channel Reach CP to LP	Length (Ft)	Velocity (FPS)	Tatum Steps
108 R 107	7000	25	.62
107 R 106	4200	20	.47
106 R 105	4600	21	.48
105 R 103	10400	13	1.73
103 R 101	7400	16	1.00

See Plate 1 for locations

Muskingum Routing Coefficients
Sawtelle-Westwood Watershed

Channel Reach	Length (Ft)	NRCHS	Muskingum: X K (Hrs)	
101 R 103	3400	1	.30	.0833
102 R 103	6200	1	.20	"
103 R 105	4600	1	.30	"
106 R 107	5700	1	.20	"
107 R 111	7400	3	.20	"
109 R 110	3800	2	.05	"
110 R 111	7800	3	.25	"
105 R 111	8800	2	.25	"
111 R 1141	8900	4	.20	"
112 R 113	24300	7	.30	"
115 R 116	20600	7	.20	"
114 R 117	5300	1	.35	"

See Plate 2 for locations

Table 12

UNITHYDROGRAPH PARAMETERS
BALLONA CREEK WATERSHED

Subarea	Drainage Area (SQ MI)	L (MI)	Lca (MI)	S (FT/MI)	S-Graph	Basin "n"		PIC	
						Present	Future	Present	Future
8	25.0	9.6	5.6	145	Valley	.018	.015	60	75
7	19.8	8.3	5.0	150	Valley	.020	.016	50	75
6	25.5	8.7	3.8	37	Valley	.025	.021	60	80
5	12.6	9.2	5.5	123	Valley	.021	.018	40	70
4	3.5	4.2	1.9	47	Valley	.015	.016	60	80
39	3.5	4.0	2.3	259	Foothill	.027	.022	5	15
38	1.7	3.8	2.0	232	Foothill	.027	.022	5	20
37	0.5	1.7	0.9	272	Valley	.022	.019	20	40
36	1.1	3.2	1.6	235	Foothill	.032	.029	15	25
35	0.9	2.0	0.9	395	Foothill	.027	.018	10	20
34	1.0	2.5	1.1	312	Foothill	.027	.024	15	25
33	3.2	3.1	2.0	177	Valley	.027	.021	35	50
32	4.9	4.8	3.6	97	Valley	.017	.019	45	80
31	4.5	4.2	2.3	57	Valley	.017	.019	50	80
2	2.4	3.0	2.1	35	Valley	.015	.017	50	80
1	9.6	7.6	3.8	58	Valley	.020	.018	40	60

See plate 1

Table 13
Modified Unit Hydrograph Parameters
Sawtelle-Westwood Watershed

Subarea	DA (SQ MI)	L (MI)	Lca (MI)	S (Ft/MI)	S-Graph	Percent Impervious Cover		Basin "n"	
						Present	Future	Present	Future
1	3.25	3.8	2.1	253	Foothill	5	15	.027	.024
2	1.17	2.6	1.5	269	Foothill	5	15	.017	.024
3	.50	1.3	0.6	369	Foothill	20	25	.017	.024
4	.14								
5	.54	1.6	0.7	241	Foothill	20	40	.027	.027
6	.96	2.5	1.3	312	Foothill	15	25	.030	.030
7	.31	1.2	0.6	263	Valley	20	40	.022	.022
8	1.34	1.0	0.2	435	Foothill	2	2	.027	.027
9	1.03	2.5	1.3	304	Foothill	10	20	.027	.027
10	.65	1.4	0.6	311	Valley	40	50	.050	.050
11	1.35	2.1	0.9	119	Valley	25	40	.022	.024
12	1.06	3.0	1.5	257	Foothill	15	25	.032	.032
13	4.63	4.9	1.9	116	Valley	45	60	.022	.024
14	0.50	1.7	0.8	71	Valley	45	70	.022	.024
15	0.52	1.7	0.9	276	Valley	20	30	.022	.022
16	4.39	3.9	2.2	63	Valley	50	70	.022	.024

See plate 2

TABLE 14
SUMMARY STANDARD PROJECT FLOOD AND 100-YEAR
PEAK DISCHARGES, BALLONA CREEK CHANNEL

C.P.	DA (SQ MI)	CAPACITY (CFS)	SPF PRESENT RESTRICTED (CFS)	100 YR PRESENT RESTRICTED (CFS)	SPF FUTURE RESTRICTED (CFS)	100 YR FUTURE RESTRICTED (CFS)	SPF FUTURE UNRESTRICTED (CFS)	100 YR FUTURE UNRESTRICTED (CFS)
108	25	30000	23000	18500	28000	22500	28000	22500
1072 U	26	18000	23000	18400	25400	22500	28000	22500
1071 U		17200	28000	20800	26000	22500 ✓	30000	24500
107	45	41000	36000	29000	39000	34000	42000	34000
1062		39400	39000	31000	42000	35000	43000	35000
10621	70	39400	43000	34500	46400	41500	51000	41500
106	70	48000	45000	36000	49000	43000	53000	43000
105	85	50000	50000	40000	56000	45500	56000	45500
1032	88	37700	50000	40000	50000	46000	57000	46000
1031	89	39300	37700	(R) 37700	37700	37700	57000	46000
103	112	57000	54000	44000	54000	51000	64000	53000
1012	118	53100	54300	44000	54300	51000	64000	53000
101	120	72000	61000	49000	63000	54000	68000	56000

(R) = Restricted

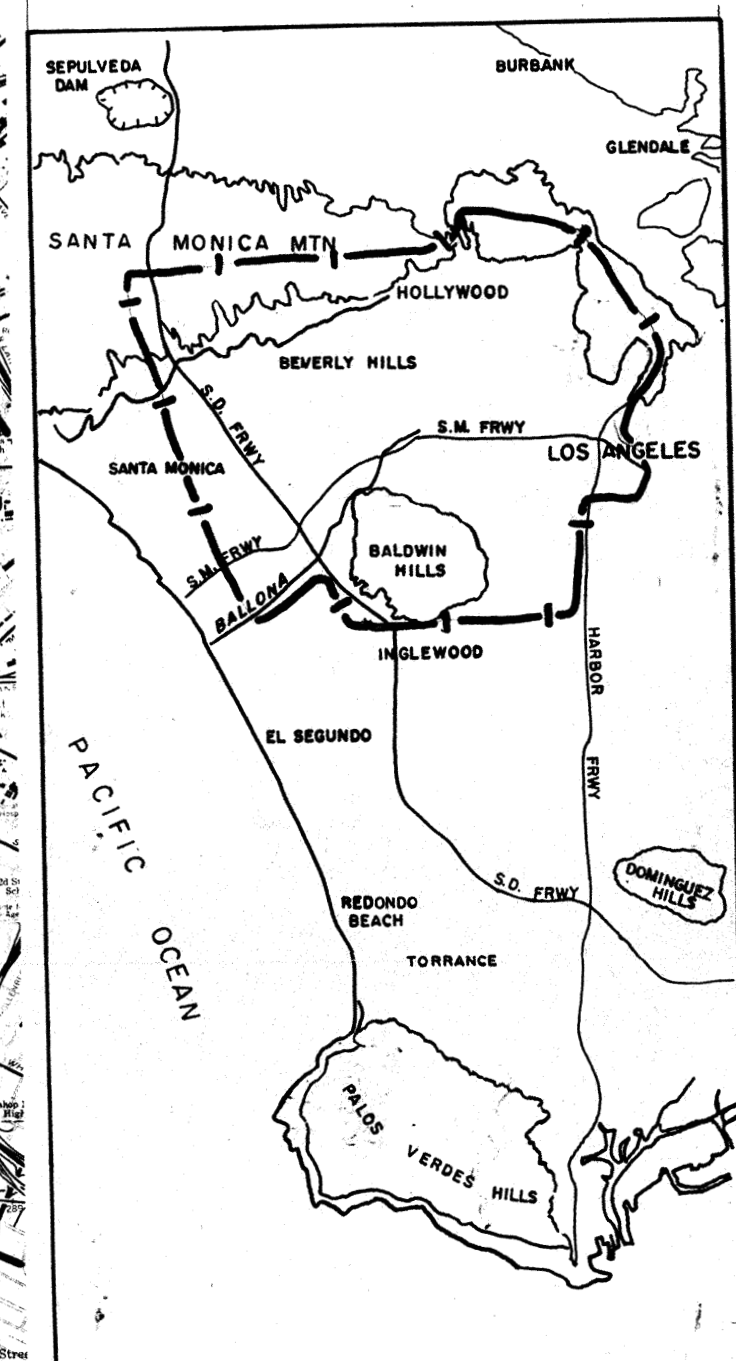
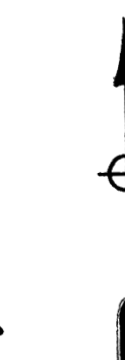
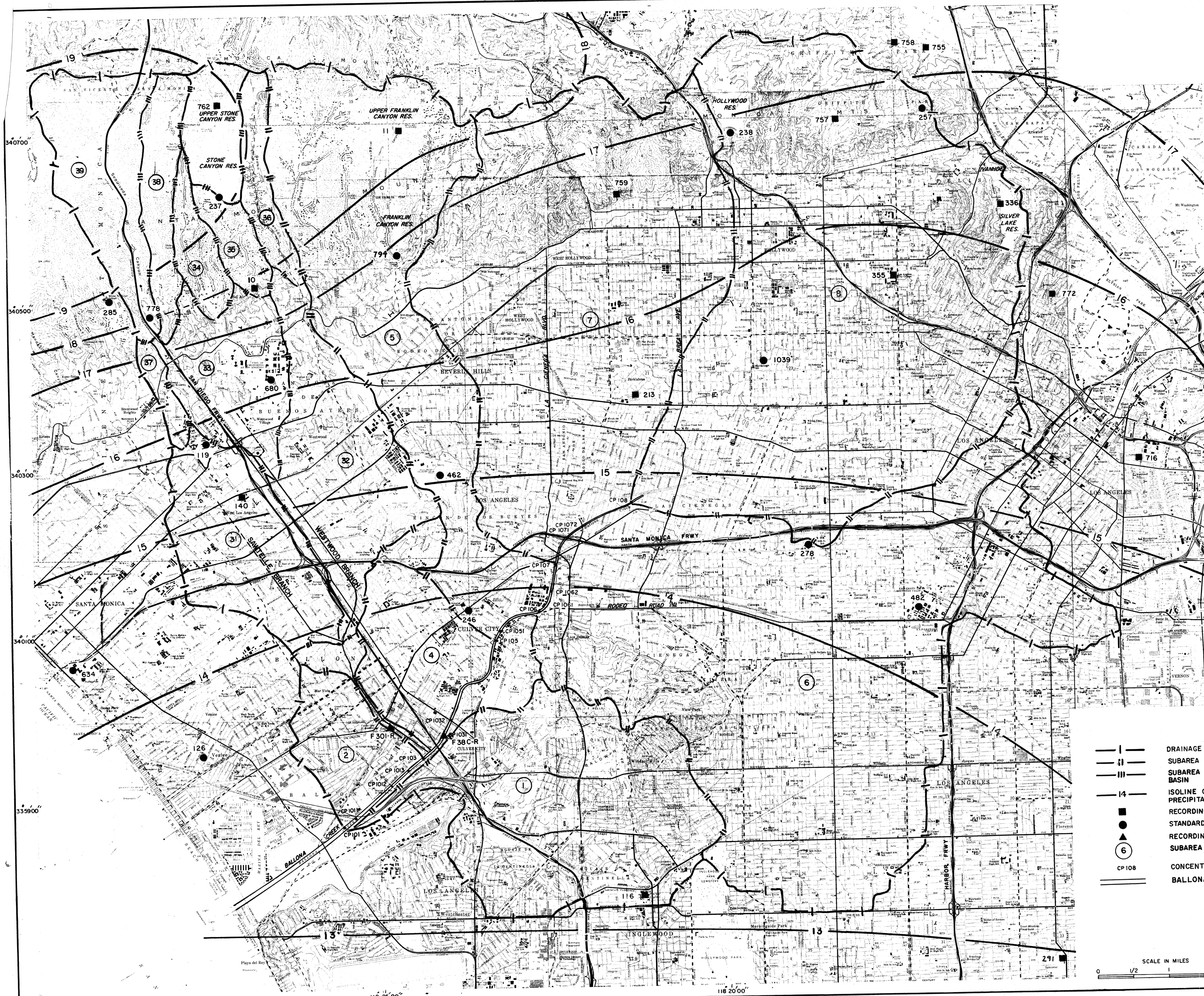
See pl. 27-29 and 33-35

Table 15

Peak Discharges
Sawtelle-Westwood Watershed

CP	Present		Future	
	SPF	100 YR	SPF	100 YR
101	5100	2500	5400	2700
102	2300	1100	2400	1200
1031	3100	1800	3300	2000
103	7100	4000	7700	4600
1051	1300	700	1300	800
105	7600	4300	8100	4900
106	1900	1000	1900	1000
107	2300	1300	2300	1400
109	2100	1100	2100	1100
110	1400	900	1400	1000
111	9800	6400	10400	7200
112	1900	1000	1900	1000
113	7500	4900	6500	4200
1141	8400	6600	9700	8200
114	13000	10000	13000	11000
115	1300	700	1300	700
116	6800	5300	6800	5700
117	17600	13800	17600	15000

See Plate 2 for locations

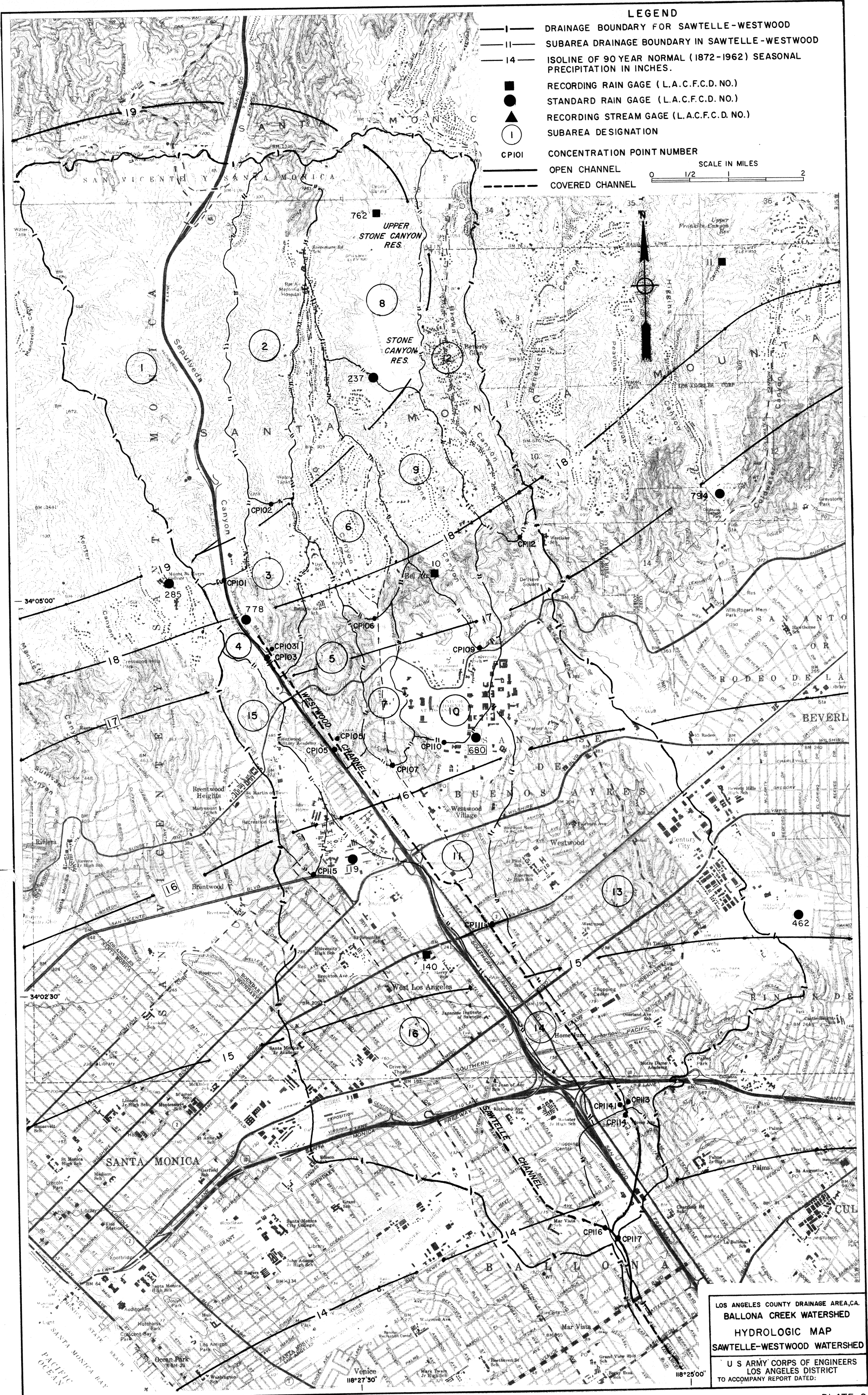


VICINITY MAP

- LEGEND**
- I — DRAINAGE BOUNDARY FOR BALLONA CREEK BASIN
 - II — SUBAREA DRAINAGE BOUNDARY IN BALLONA CREEK BASIN
 - III — SUBAREA DRAINAGE BOUNDARY IN SAWTELLE WESTWOOD BASIN
 - 14 — ISOLINE OF 90 YEAR NORMAL (1872-1962) SEASONAL PRECIPITATION IN INCHES
 - RECORDING RAIN GAGE (L.A.C.F.C.D. NO.)
 - STANDARD RAIN GAGE (L.A.C.F.C.D. NO.)
 - ▲ RECORDING STREAM GAGE (L.A.C.F.C.D. NO.)
 - ⑥ SUBAREA DESIGNATION
 - CP 108 CONCENTRATION POINT NUMBER
 - BALLONA CREEK CHANNEL

SCALE IN MILES
0 1/2 1 2

LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
HYDROLOGIC MAP
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

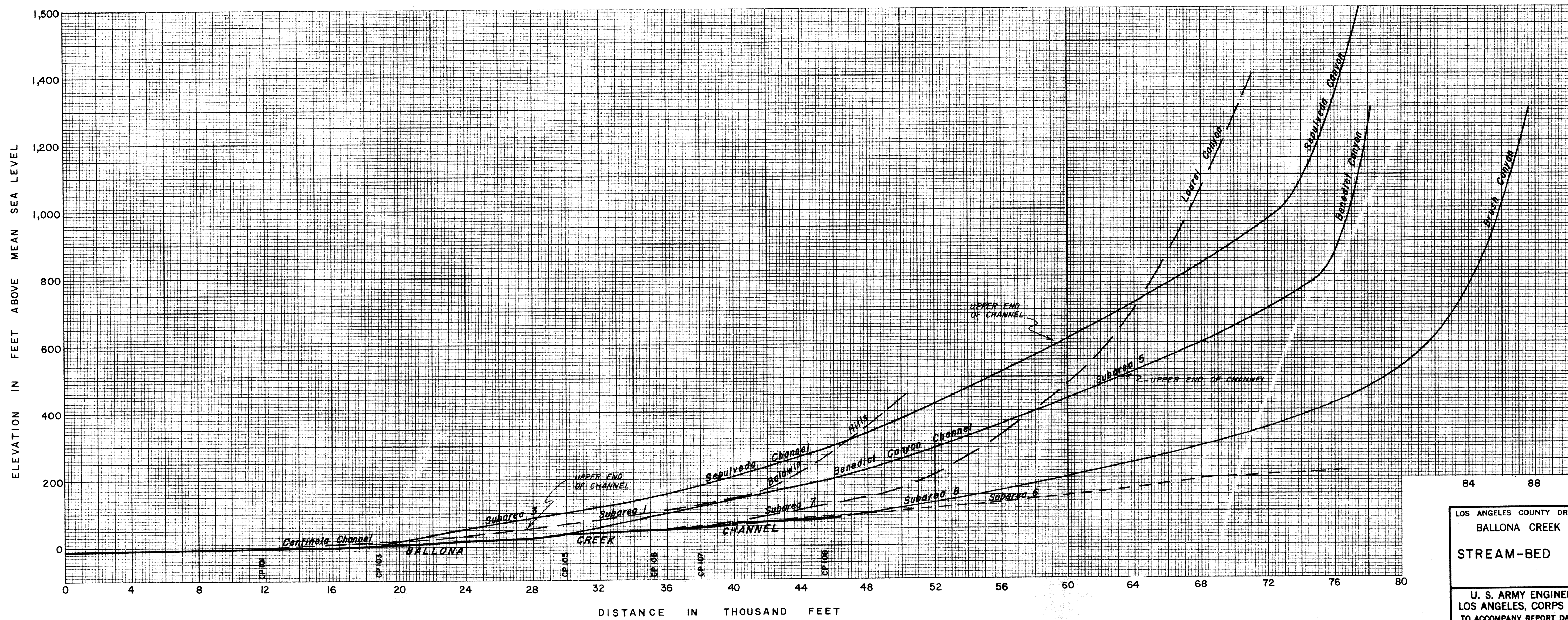


LEGEND

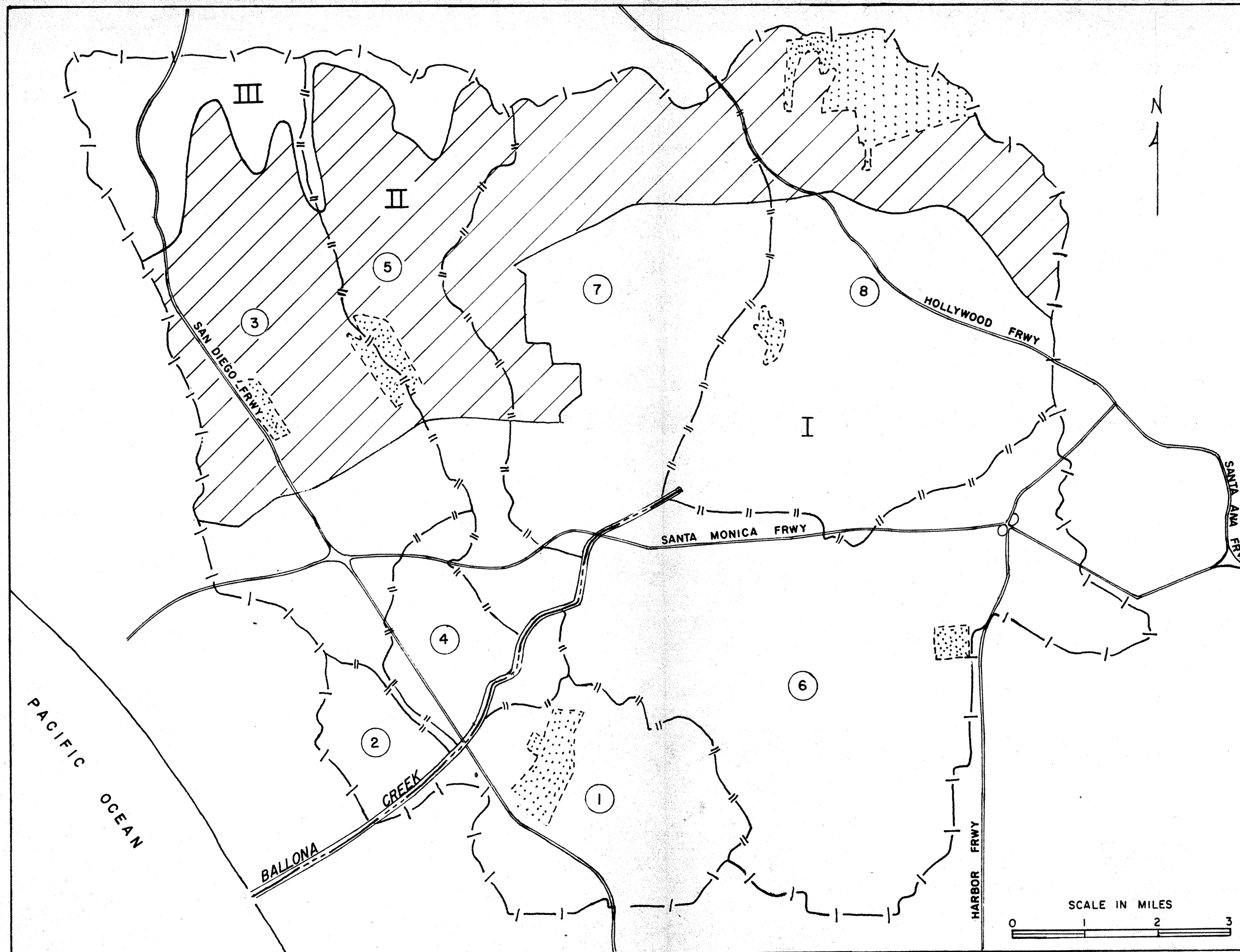
- I — DRAINAGE BOUNDARY FOR SAWTELLE-WESTWOOD
- II — SUBAREA DRAINAGE BOUNDARY IN SAWTELLE-WESTWOOD
- 14 — ISOLINE OF 90 YEAR NORMAL (1872-1962) SEASONAL PRECIPITATION IN INCHES.
- RECORDING RAIN GAGE (L.A.C.F.C.D. NO.)
- STANDARD RAIN GAGE (L.A.C.F.C.D. NO.)
- ▲ RECORDING STREAM GAGE (L.A.C.F.C.D. NO.)
- SUBAREA DESIGNATION
- CPI01 CONCENTRATION POINT NUMBER
- OPEN CHANNEL
- - - COVERED CHANNEL

SCALE IN MILES
0 1/2 1 2

LOS ANGELES COUNTY DRAINAGE AREA, CA.
BALLONA CREEK WATERSHED
HYDROLOGIC MAP
SAWTELLE-WESTWOOD WATERSHED
U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
TO ACCOMPANY REPORT DATED:



LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
STREAM-BED PROFILES
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:



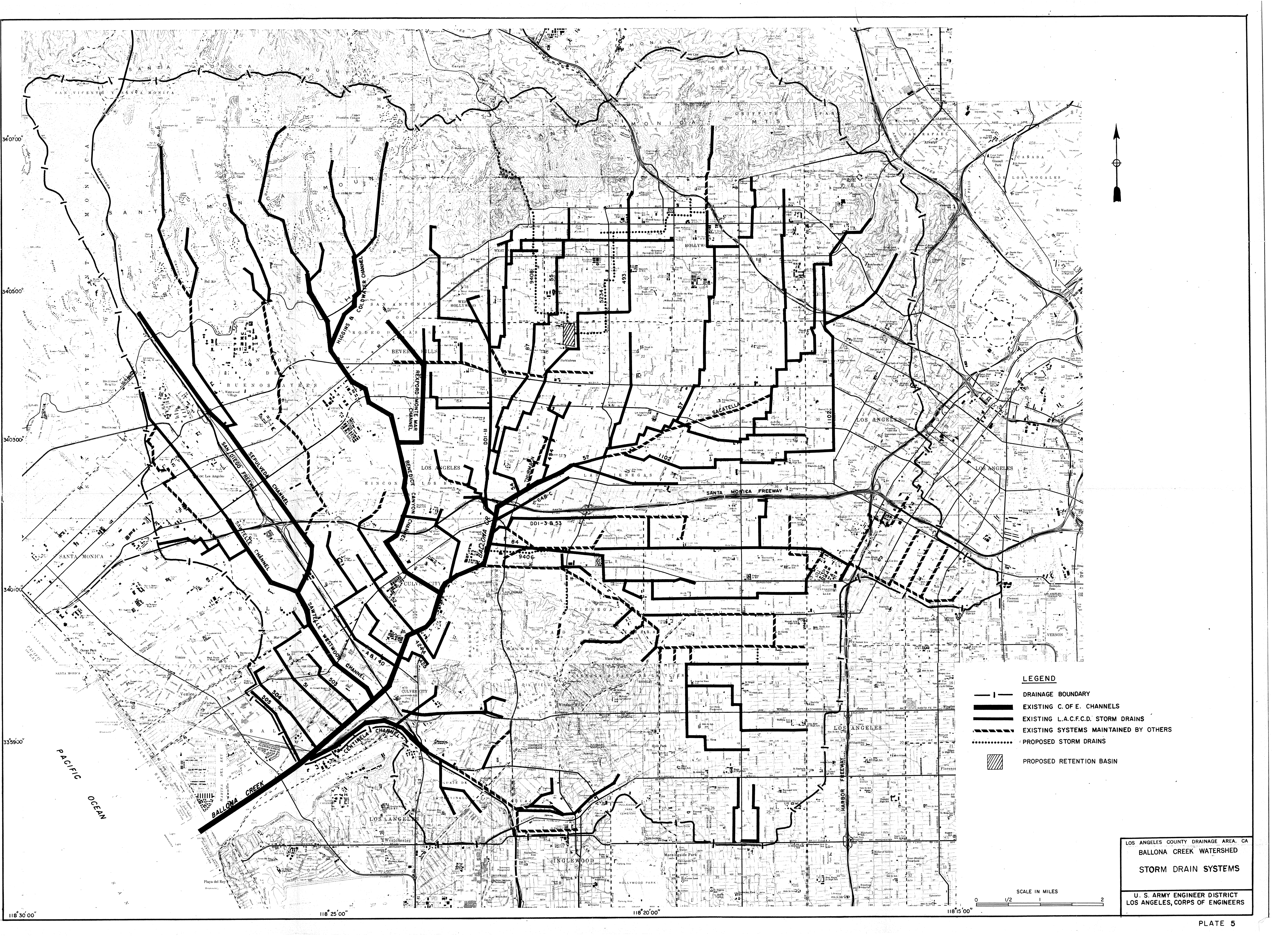
LEGEND

- I — DRAINAGE AREA BOUNDARY
- II — DRAINAGE SUBAREA BOUNDARY
- ⑧ SUBAREA DESIGNATION
- I 70-100 % IMPERVIOUS
- II 30-50 % IMPERVIOUS
- III 5-10 % IMPERVIOUS
- ▨ PARK

LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED

PERCENT IMPERVIOUS COVER
ULTIMATE CONDITIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

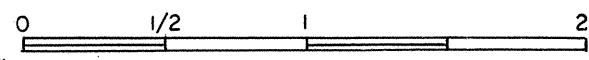


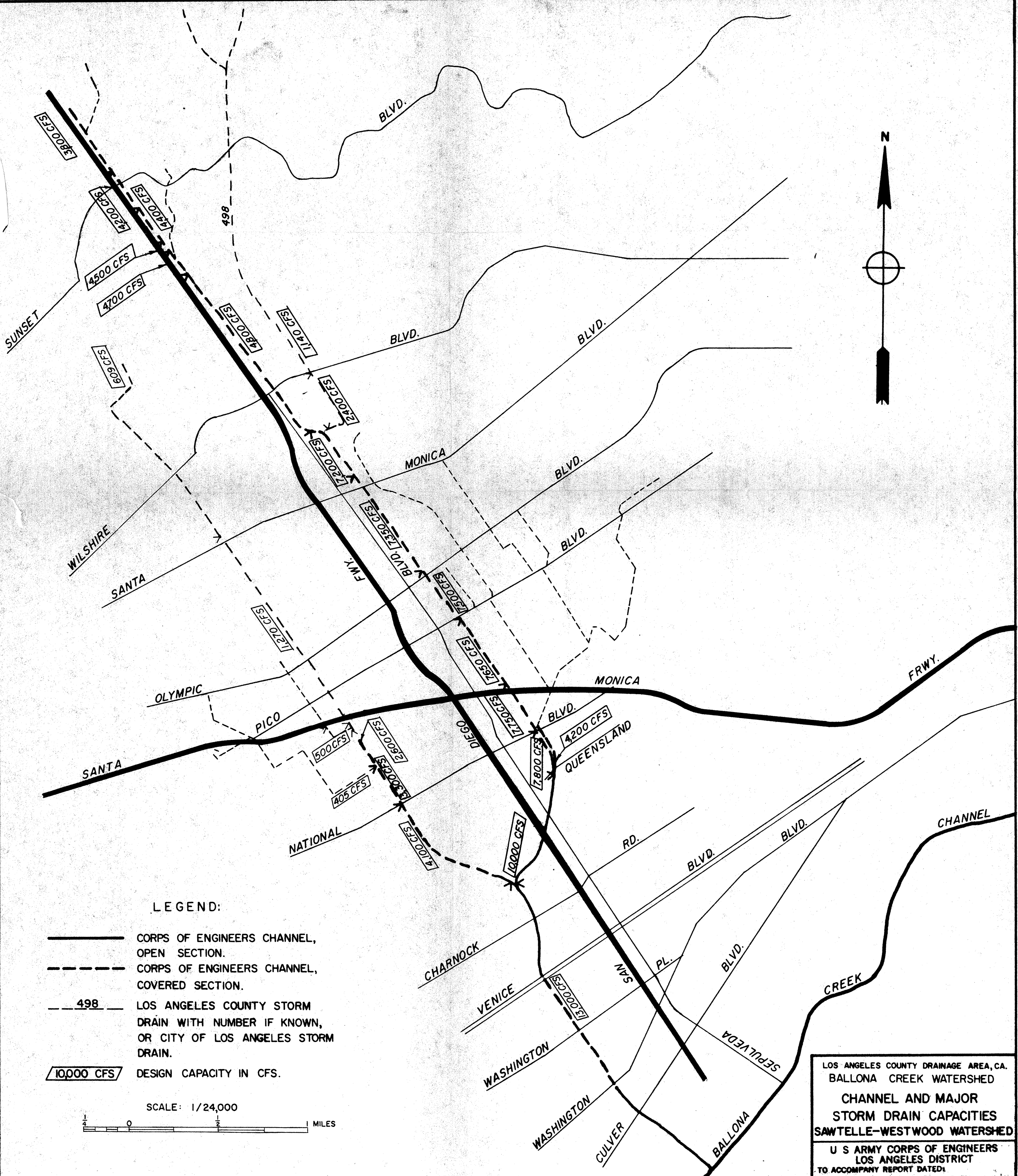
LEGEND

- DRAINAGE BOUNDARY
- EXISTING C.O.F.E. CHANNELS
- EXISTING L.A.C.F.C.D. STORM DRAINS
- EXISTING SYSTEMS MAINTAINED BY OTHERS
- PROPOSED STORM DRAINS
- ▨ PROPOSED RETENTION BASIN

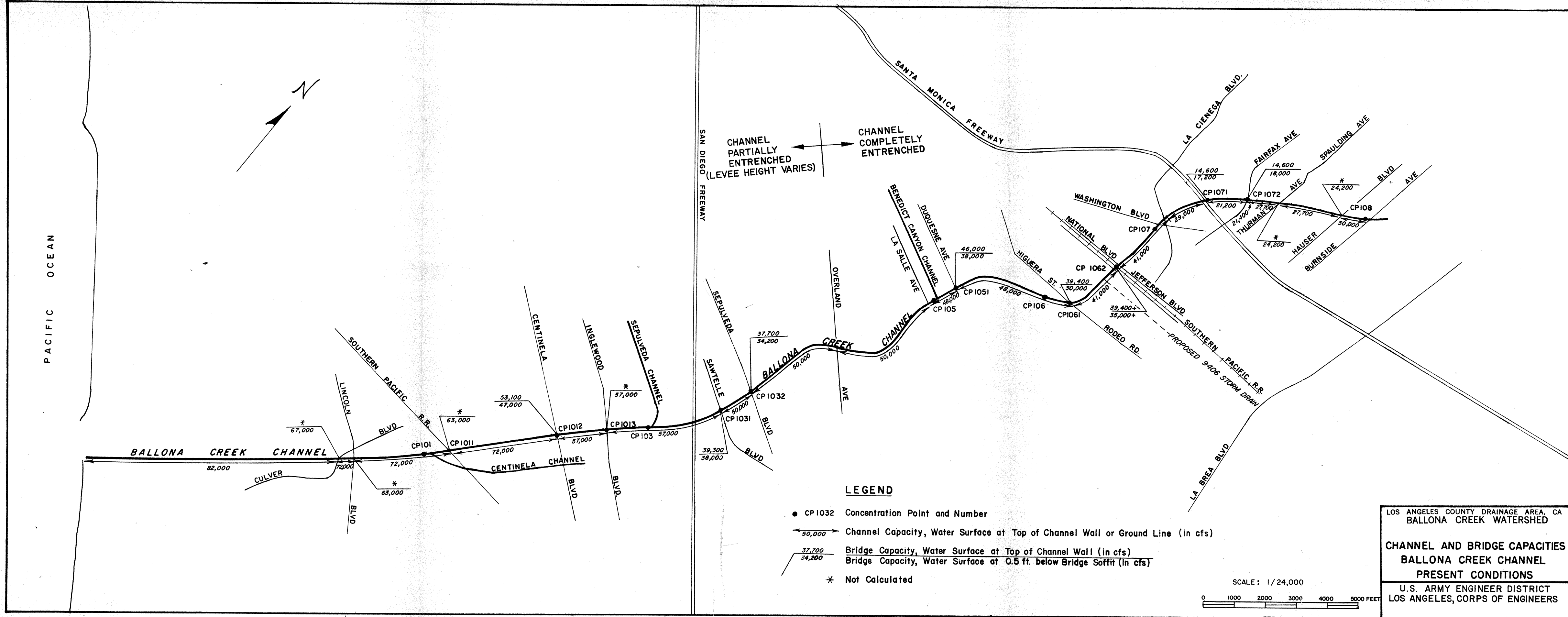
LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
STORM DRAIN SYSTEMS
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

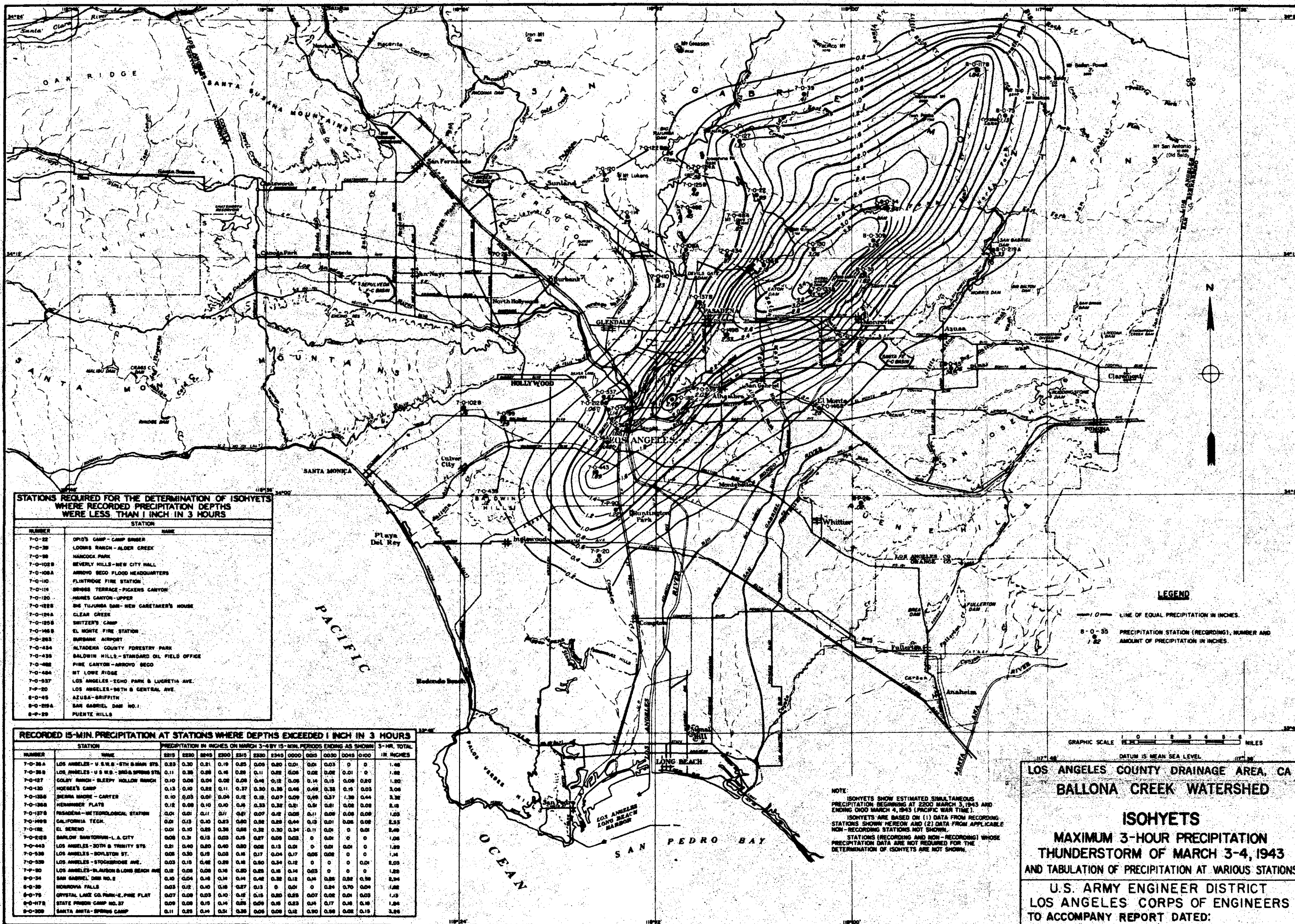
SCALE IN MILES

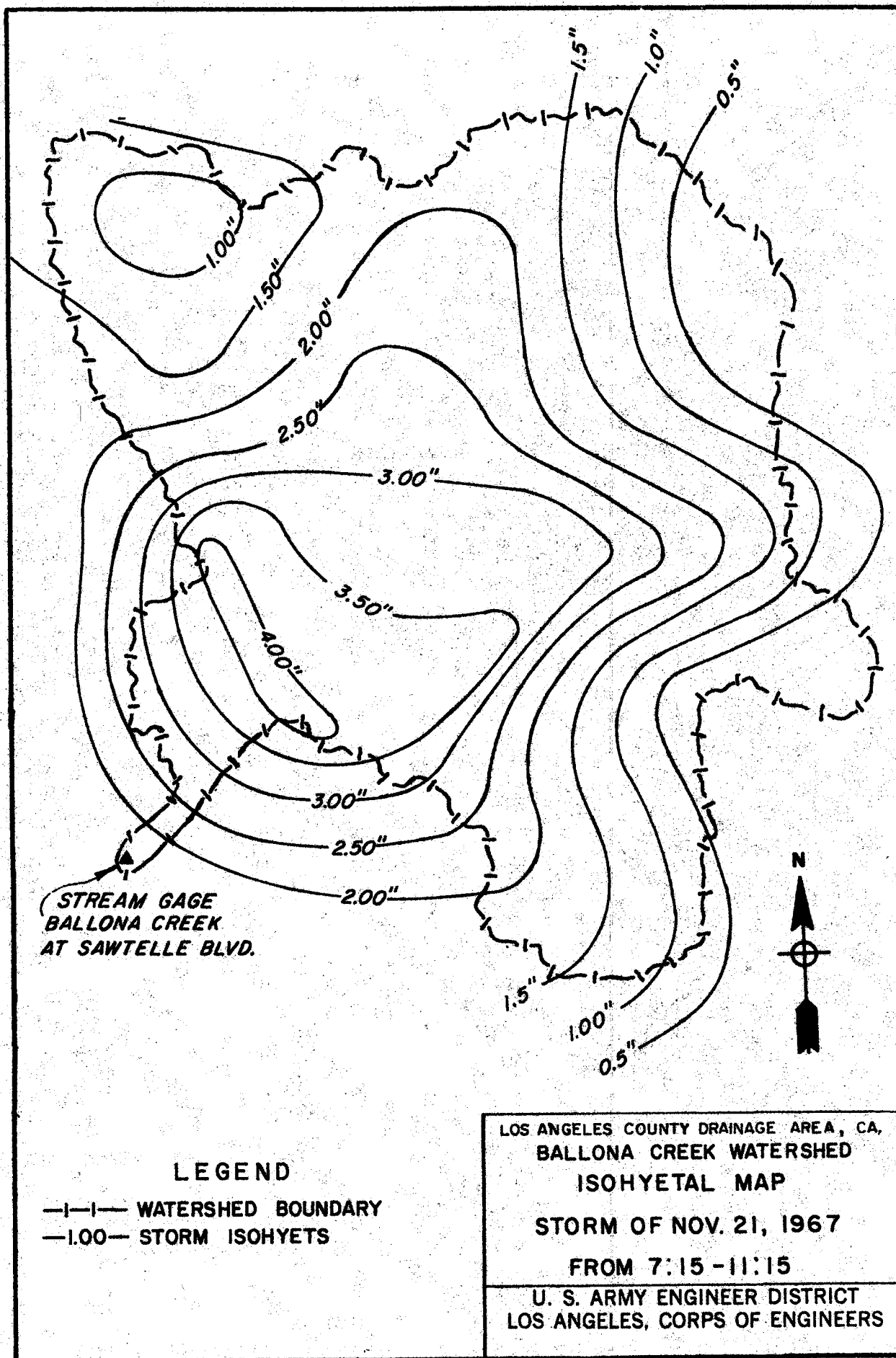


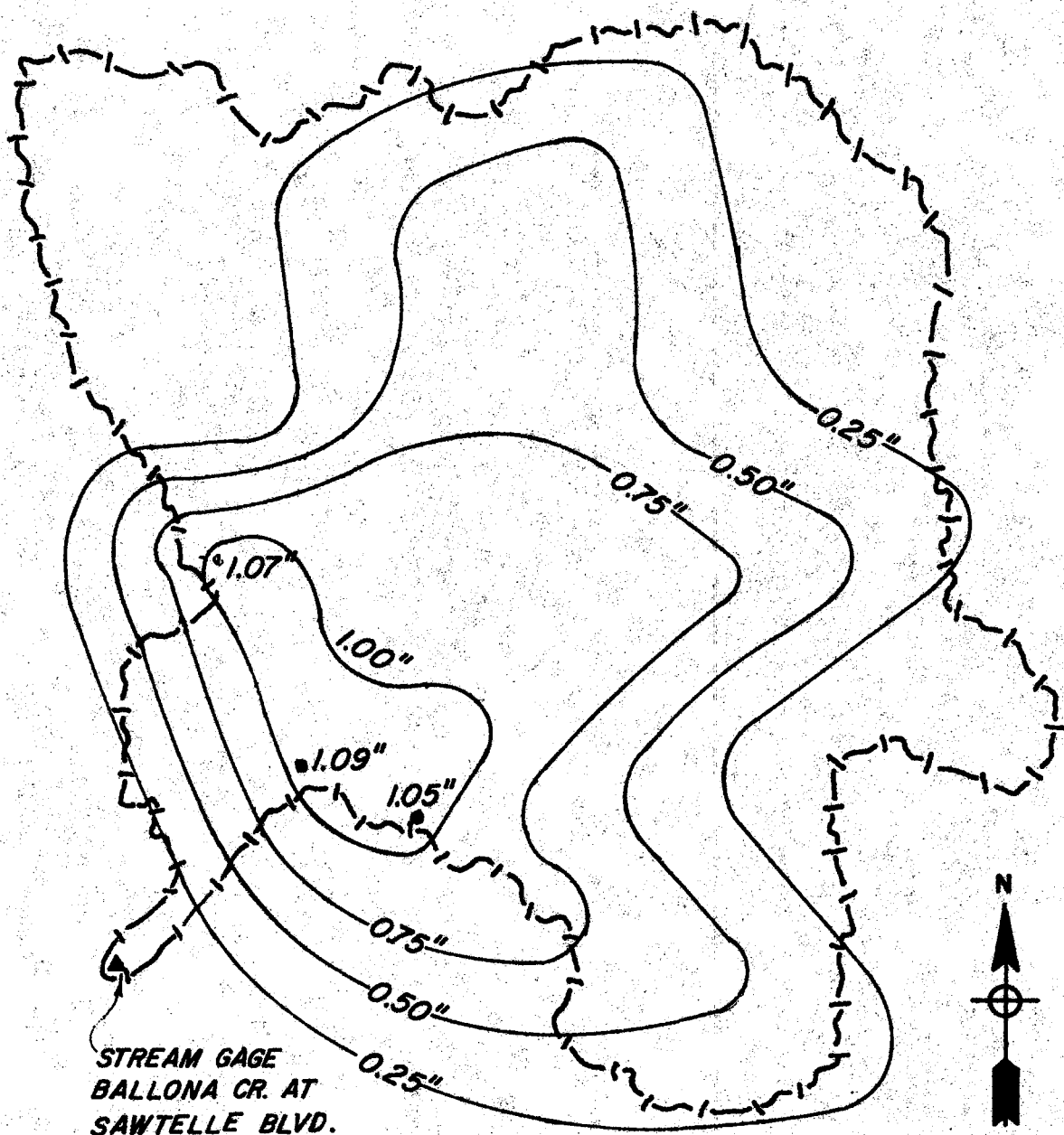


LOS ANGELES COUNTY DRAINAGE AREA, CA.
 BALLONA CREEK WATERSHED
**CHANNEL AND MAJOR
 STORM DRAIN CAPACITIES**
SAWTELLE-WESTWOOD WATERSHED
 U S ARMY CORPS OF ENGINEERS
 LOS ANGELES DISTRICT
 TO ACCOMPANY REPORT DATED:









LEGEND

- | — | — WATERSHED BOUNDARY
- 1.00 — MAXIMUM 15 MIN. ISOHYETS
- 1.09 STATION RAINFALL

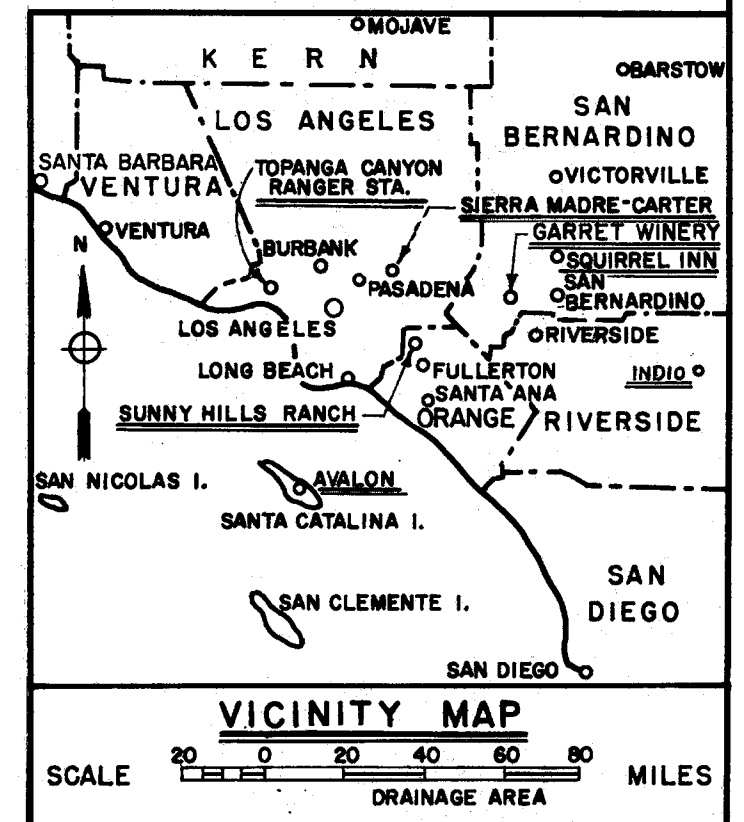
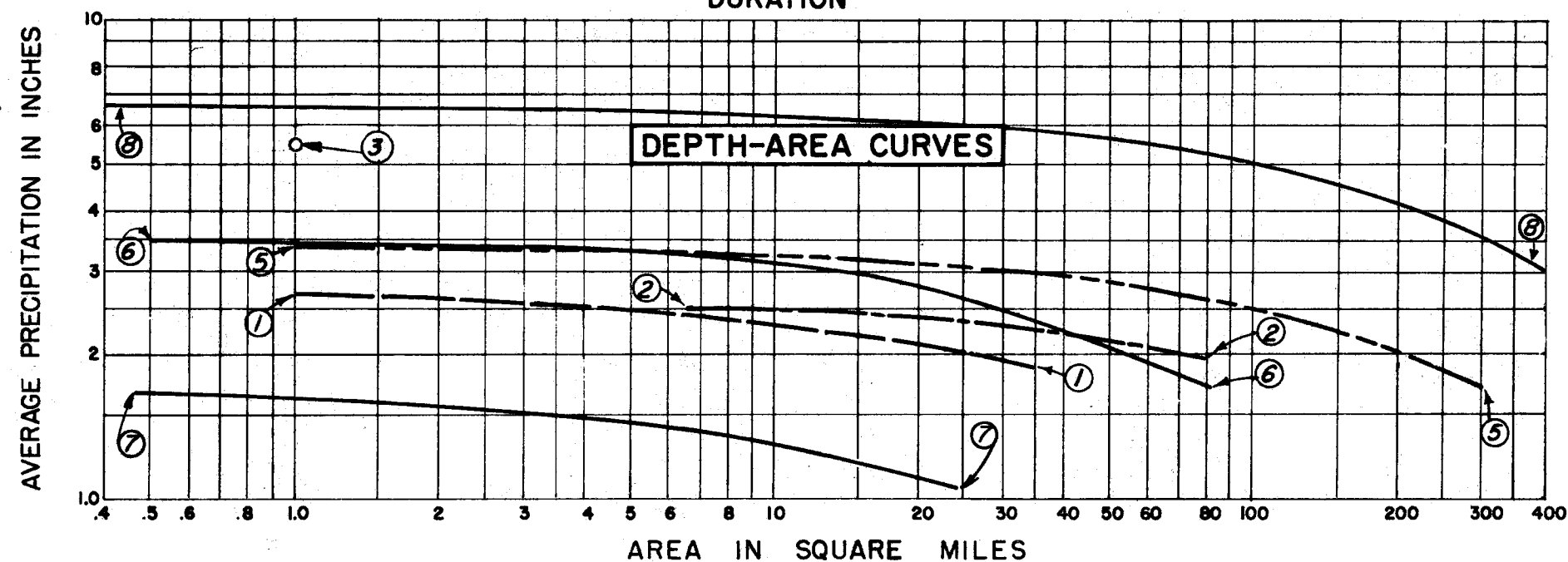
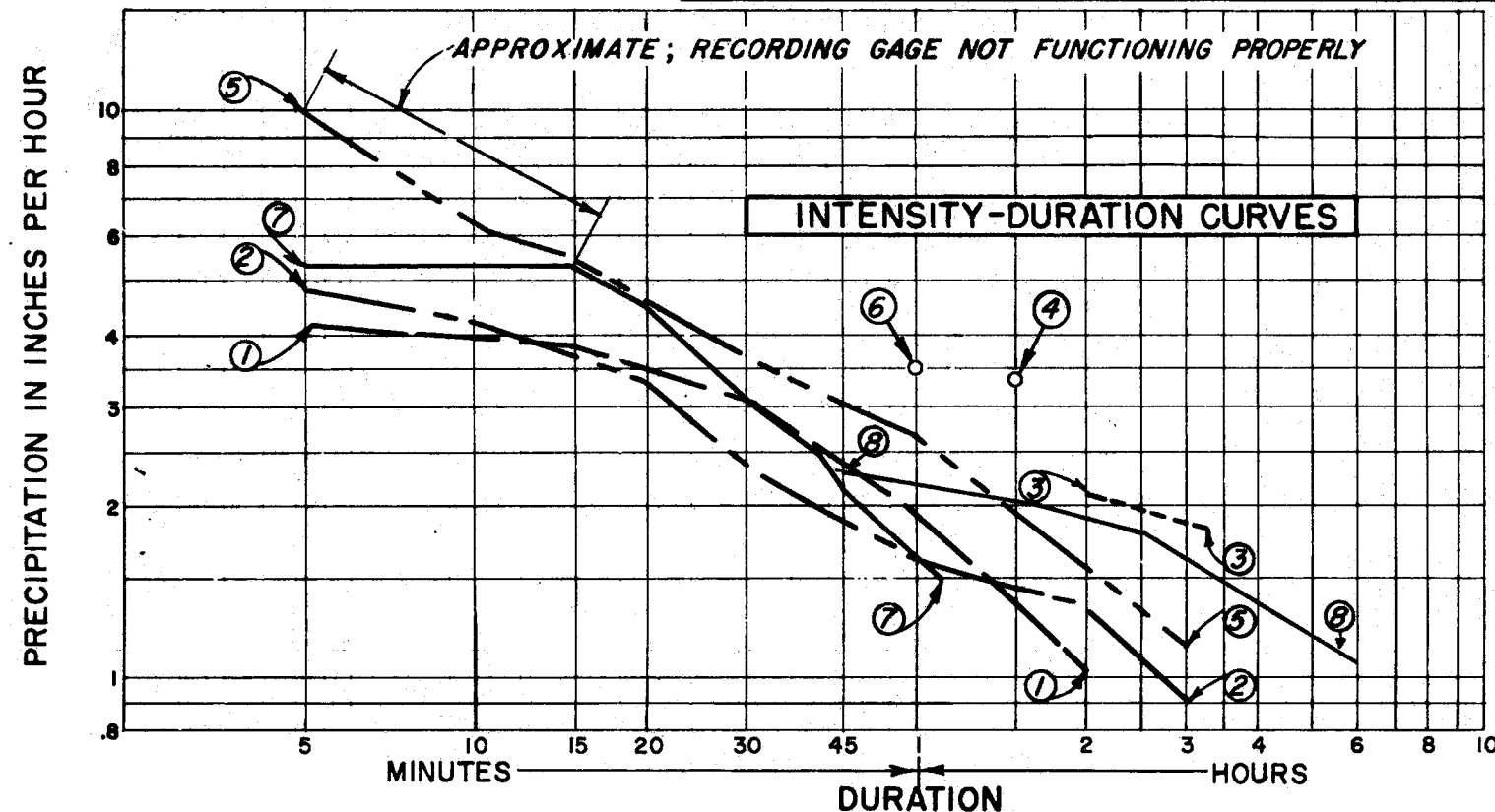
LOS ANGELES COUNTY DRAINAGE AREA, CA.
BALLONA CREEK WATERSHED
ISOHYETAL MAP

STORM OF NOV. 21, 1967

MAX. 15 MIN. ISOHYETS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

CURVE NUMBER	PRECIPITATION STATION		STORM		
	NAME	NUMBER	LOCATION	DURATION	DATE
1	SUNNY HILLS RANCH	8P98	FULLERTON, CALIF.	HR. MIN.	MAR. 14, 1941
2	TOPANGA CANYON RANGER STATION	7077	TOPANGA CANYON, CALIF.	2 0	FEB. 20, 1941
3	AVALON	7P10	AVALON, CALIF.	3 15	OCT. 21, 1941
4	SQUIRREL INN	8012	SQUIRREL INN, CALIF.	1 30	JULY 18, 1922
5	SIERRA MADRE - CARTER	70133B	SIERRA MADRE, CALIF.	3 0	MAR. 3-4, 1943
6	GARRET WINERY	—	CUCAMONGA, CALIF.	1 0	SEPT. 29, 1946
7	SANTA BARBARA (FIRE STA. # 3)	—	SANTA BARBARA, CALIF.	1 10	FEB. 4, 1958
8	INDIO (REVISED 7 MAR 73)	9PI3	INDIO, CALIF.	6 0	SEPT. 24, 1939

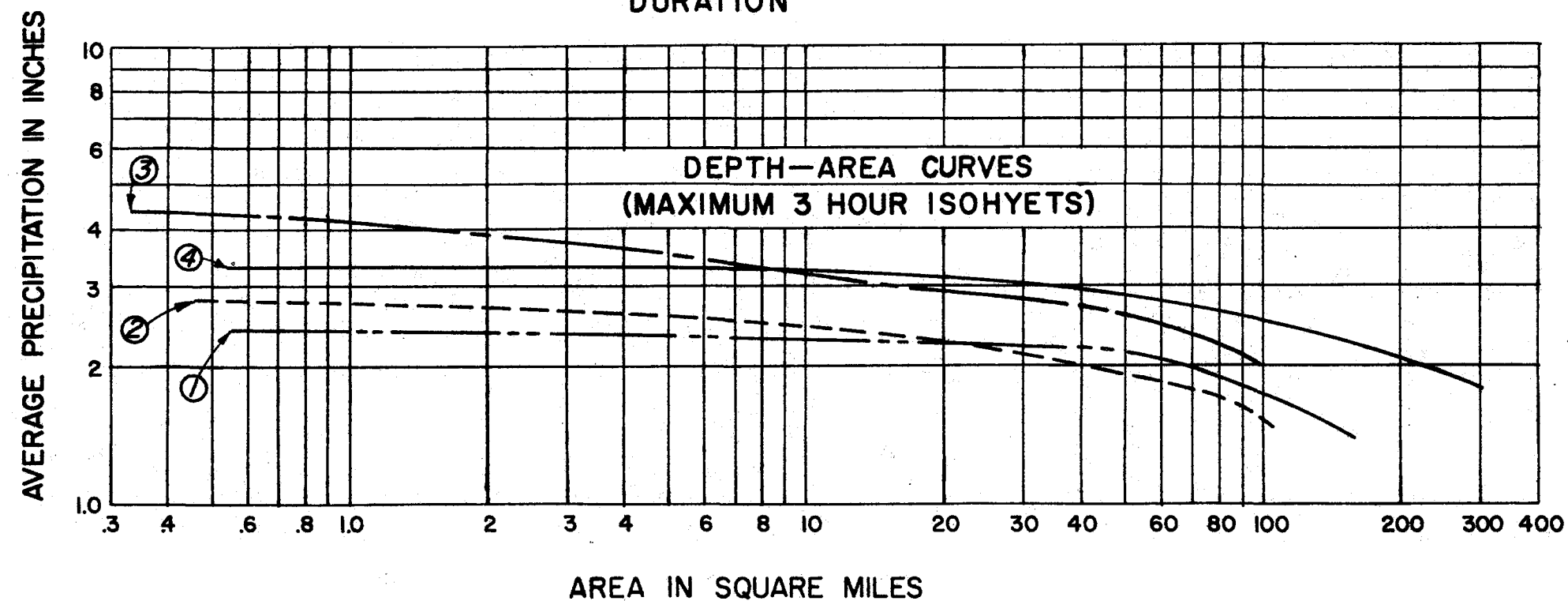
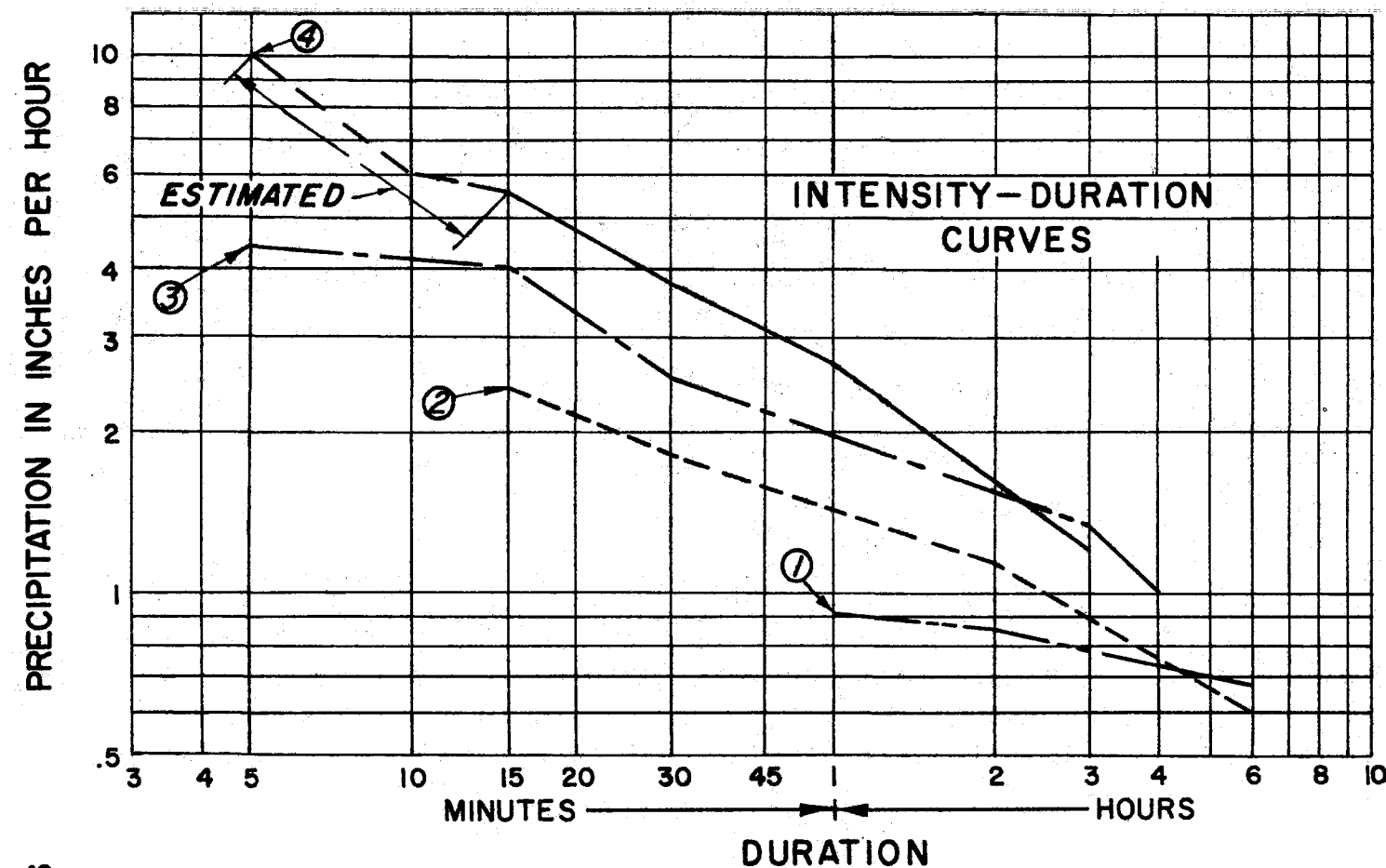


LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED

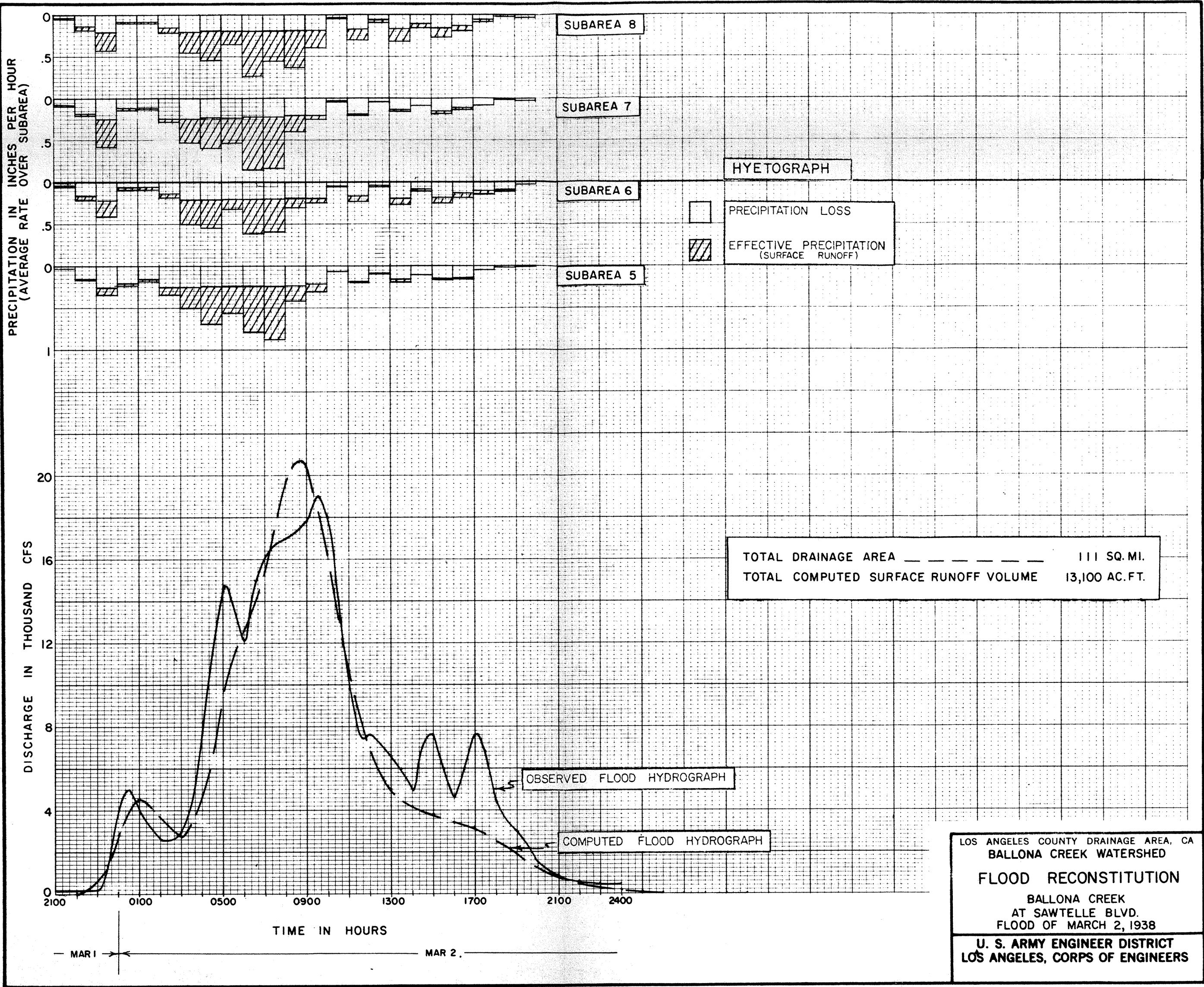
INTENSITY-DURATION AND
DEPTH-AREA RELATIONSHIPS
LOCAL STORMS IN
SOUTHERN CALIFORNIA

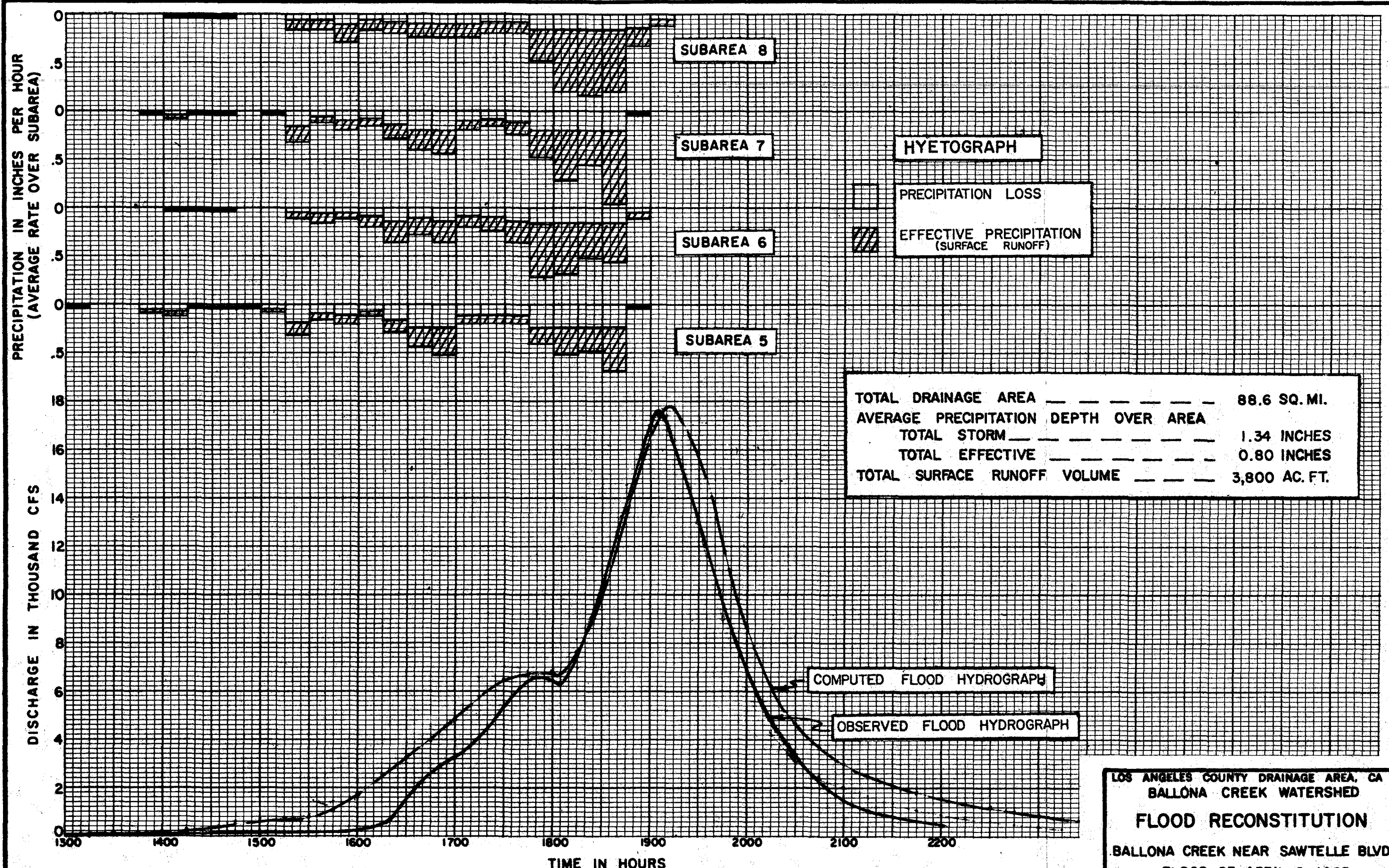
U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
TO ACCOMPANY REPORT DATED:

CURVE NUMBER	PRECIPITATION STATION		STORM DATE
	NAME	L.A. COUNTY NUMBER	
1	BEVERLY HILLS CITY HALL	228B	MAR. 1938
2	BEL AIR HOTEL	10A	DEC. 1974
3	CULVER CITY	246C	NOV. 1967
4	SIERRA MADRE-CARTER	144	MAR. 1943

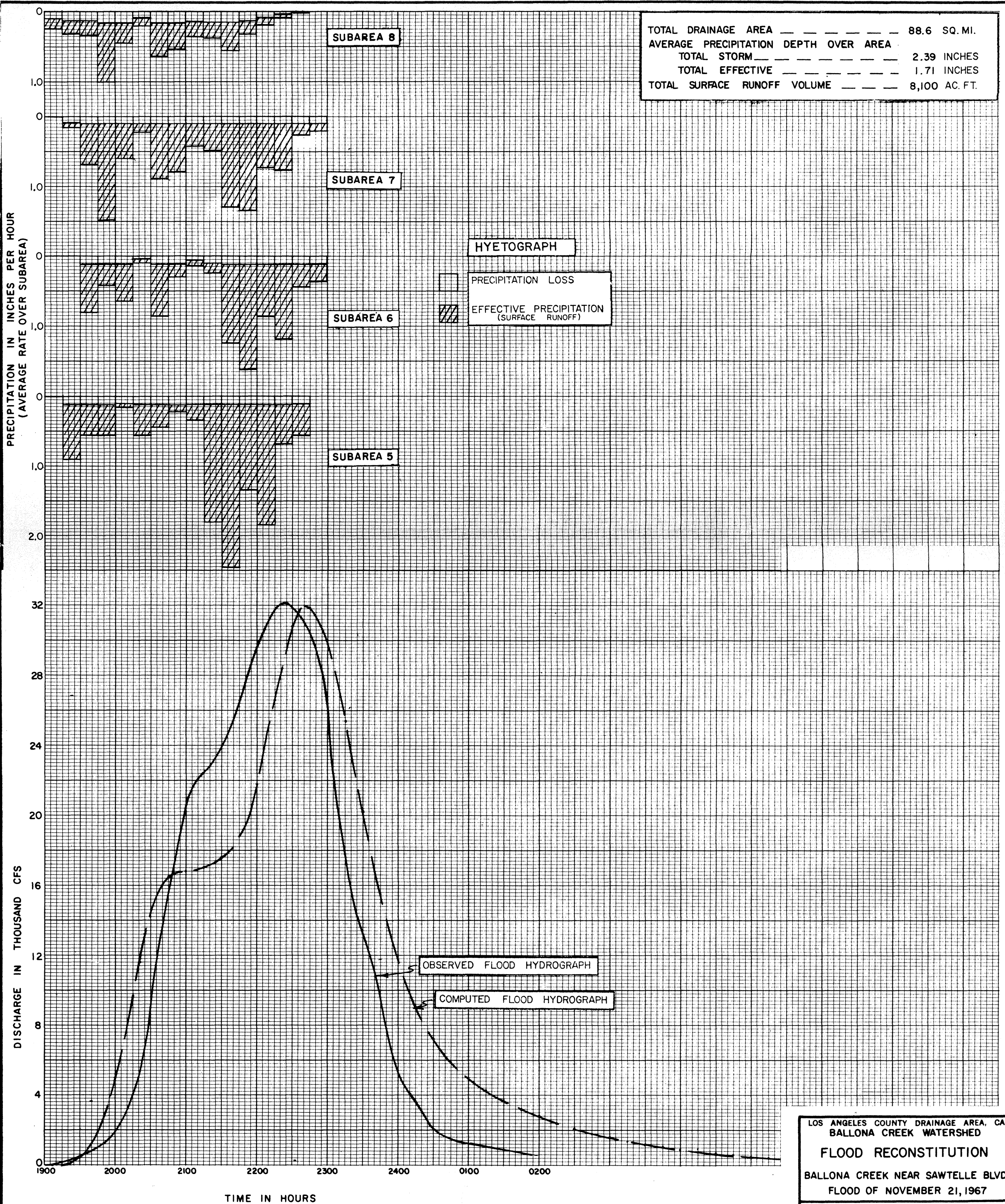


LOS ANGELES COUNTY DRAINAGE AREA, CA.
 BALLONA CREEK WATERSHED
 INTENSITY-DURATION AND
 DEPTH-AREA RELATIONSHIPS
 STORMS IN
 BALLONA CREEK WATERSHED
 U. S. ARMY ENGINEER DISTRICT
 LOS ANGELES, CORPS OF ENGINEERS
 TO ACCOMPANY REPORT DATED:

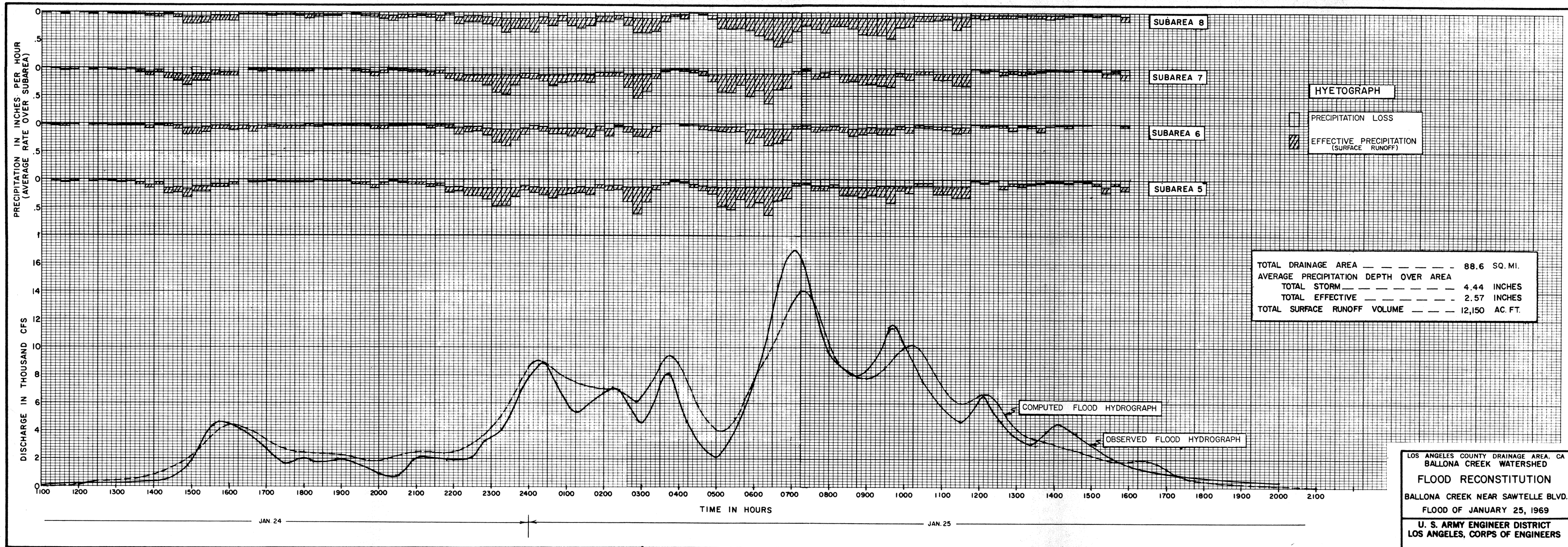


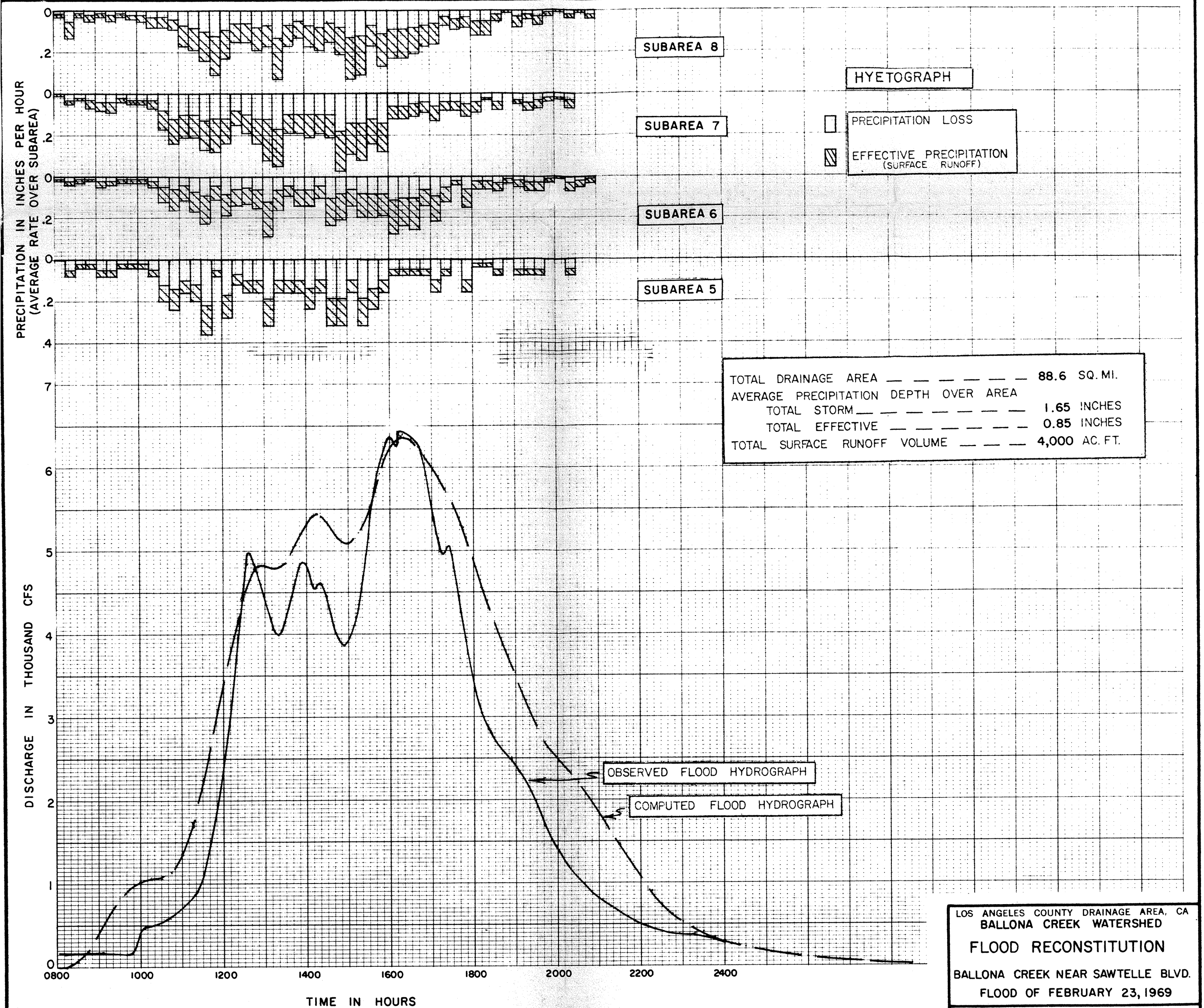


LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
FLOOD RECONSTITUTION
BALLONA CREEK NEAR SAWTELLE BLVD.
FLOOD OF APRIL 9, 1965
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS



LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
FLOOD RECONSTITUTION
BALLONA CREEK NEAR SAWTELLE BLVD.
FLOOD OF NOVEMBER 21, 1967
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

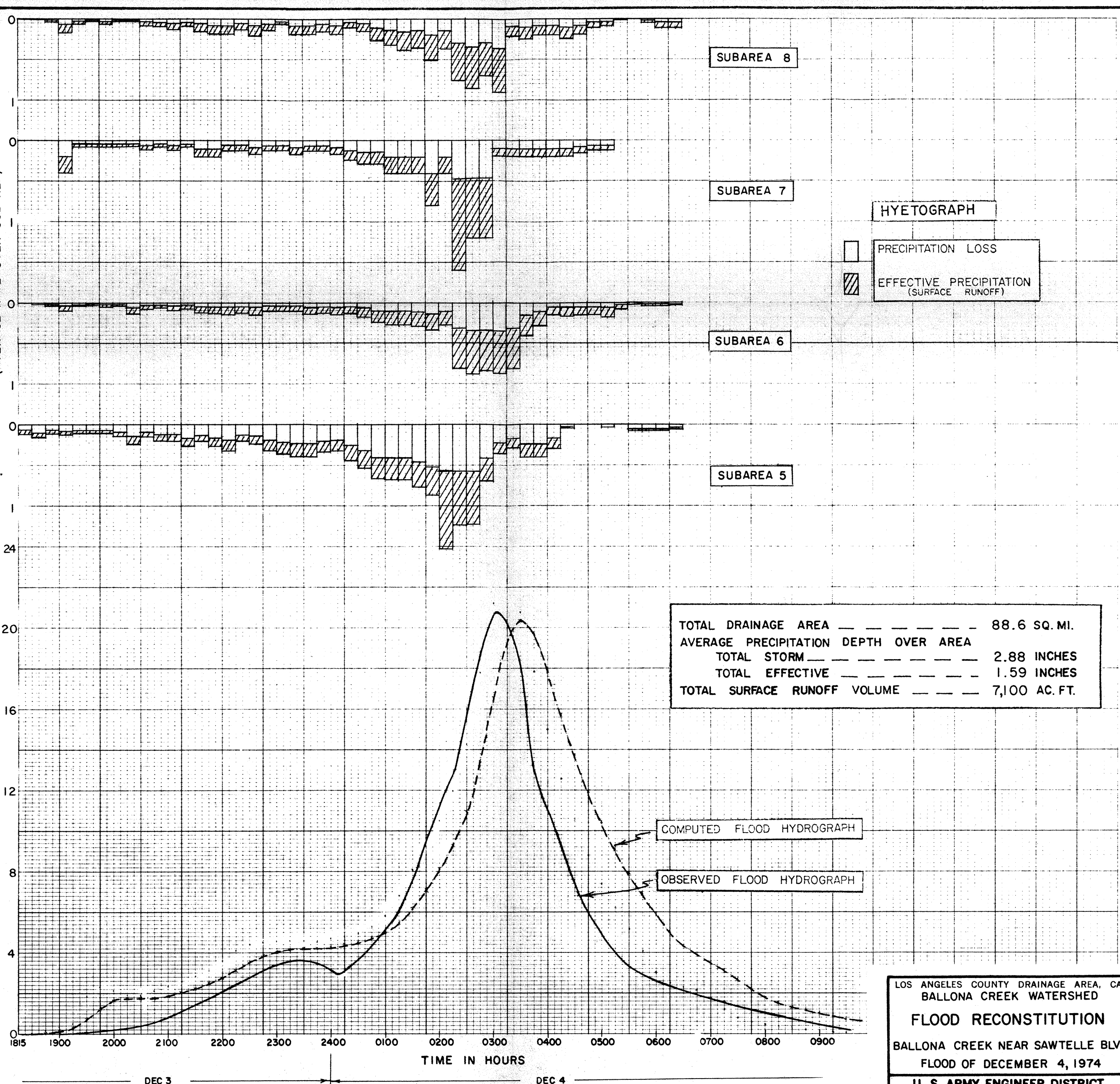




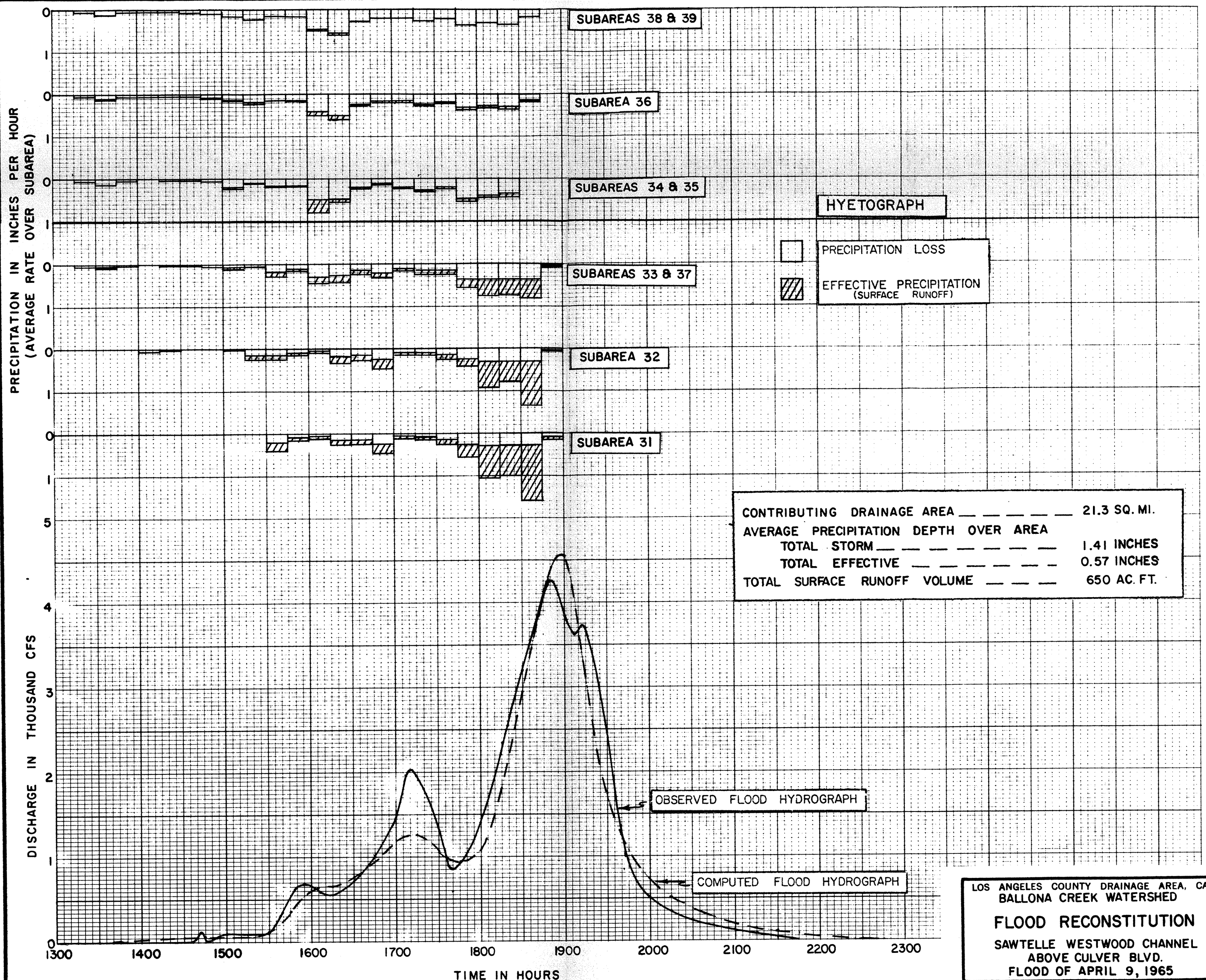
LOS ANGELES COUNTY DRAINAGE AREA, CA
 BALLONA CREEK WATERSHED
 FLOOD RECONSTITUTION
 BALLONA CREEK NEAR SAWTELLE BLVD.
 FLOOD OF FEBRUARY 23, 1969
 U. S. ARMY ENGINEER DISTRICT
 LOS ANGELES, CORPS OF ENGINEERS

PRECIPITATION IN INCHES PER HOUR
(AVERAGE RATE OVER SUBAREA)

DISCHARGE IN THOUSAND CFS



LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
FLOOD RECONSTITUTION
BALLONA CREEK NEAR SAWTELLE BLVD.
FLOOD OF DECEMBER 4, 1974
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS



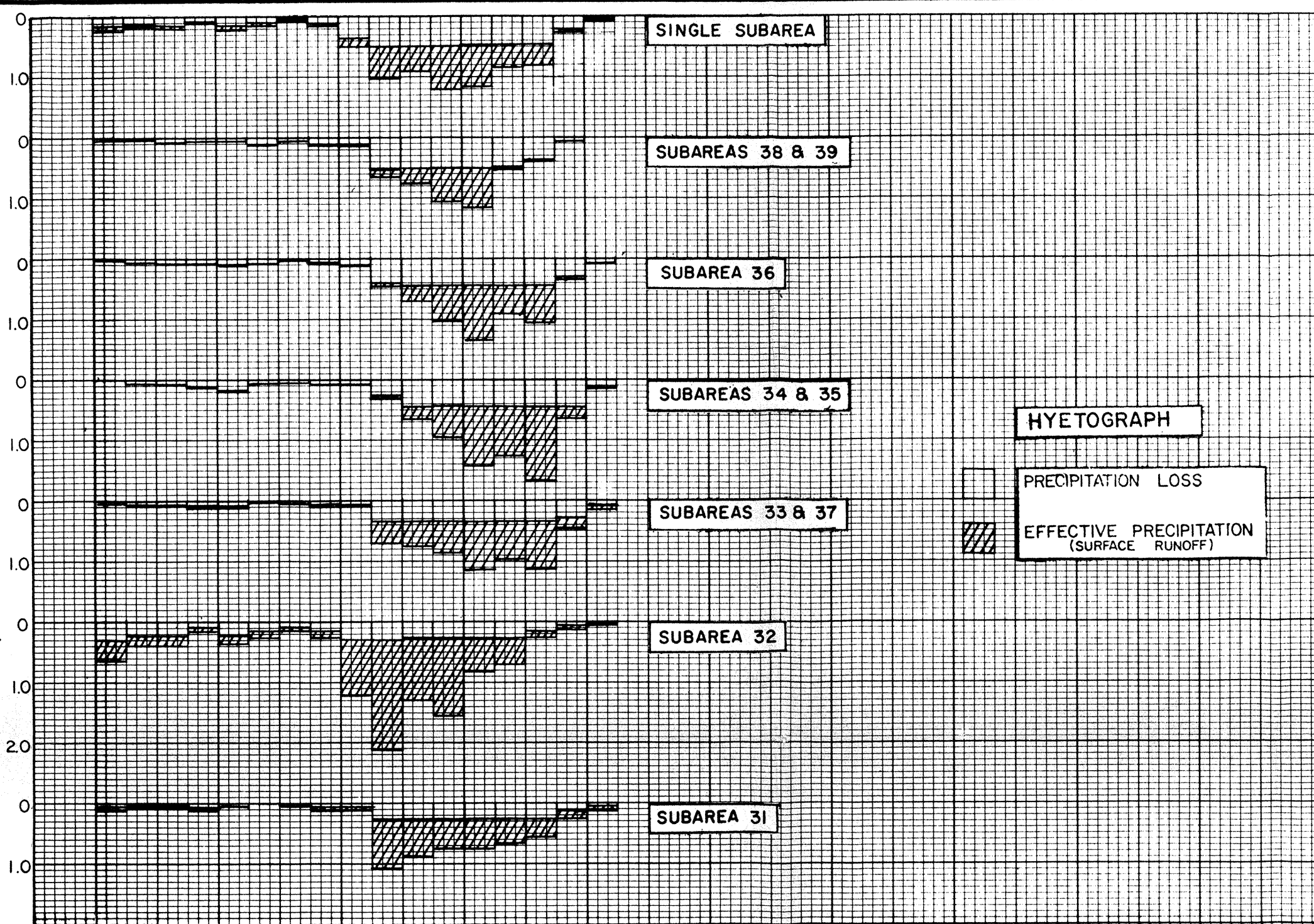
LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED

FLOOD RECONSTITUTION

SAWTELLE WESTWOOD CHANNEL
ABOVE CULVER BLVD.
FLOOD OF APRIL 9, 1965

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PRECIPITATION IN INCHES PER HOUR
(AVERAGE RATE OVER SUBAREA)

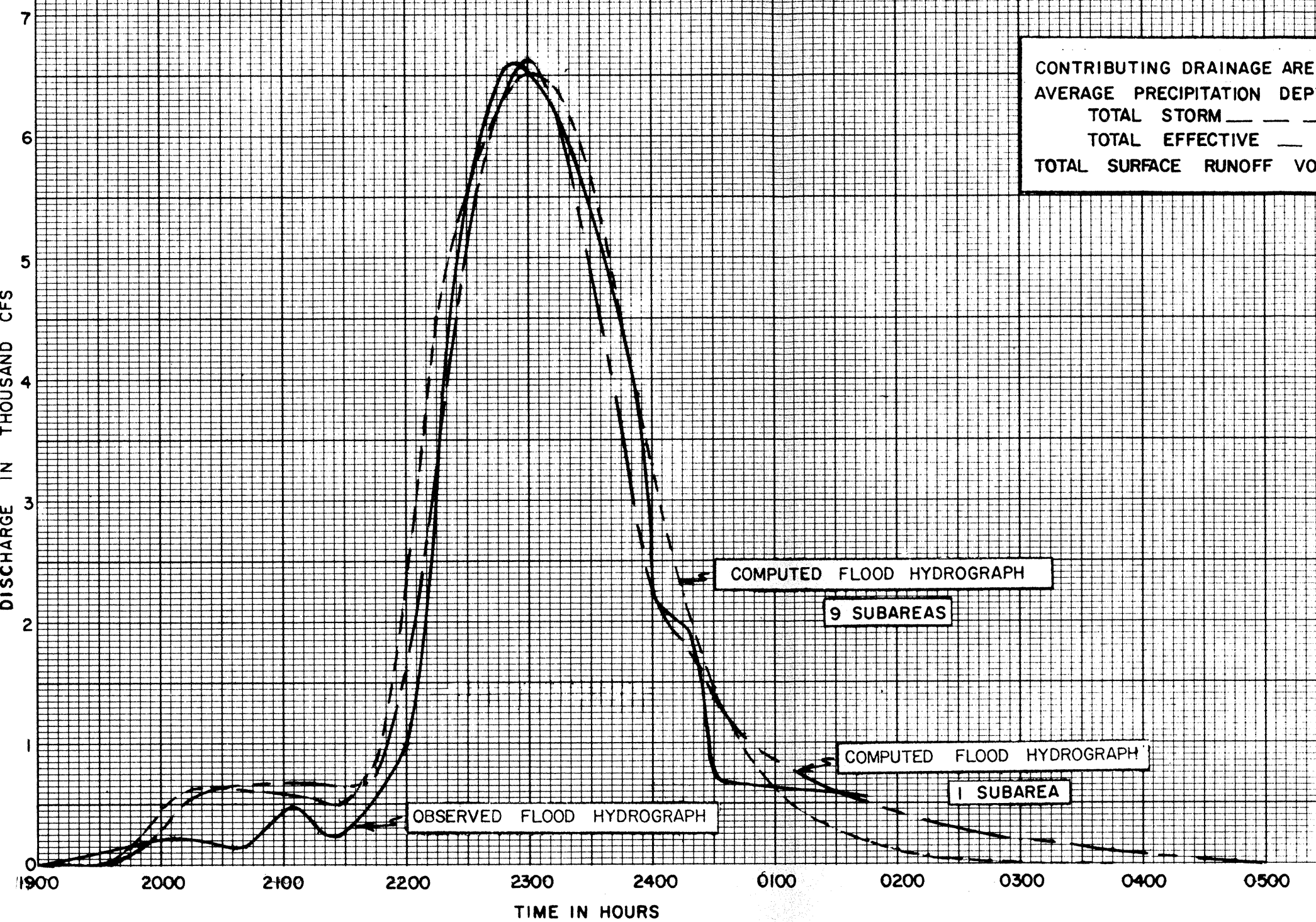


HYETOGRAPH

PRECIPITATION LOSS

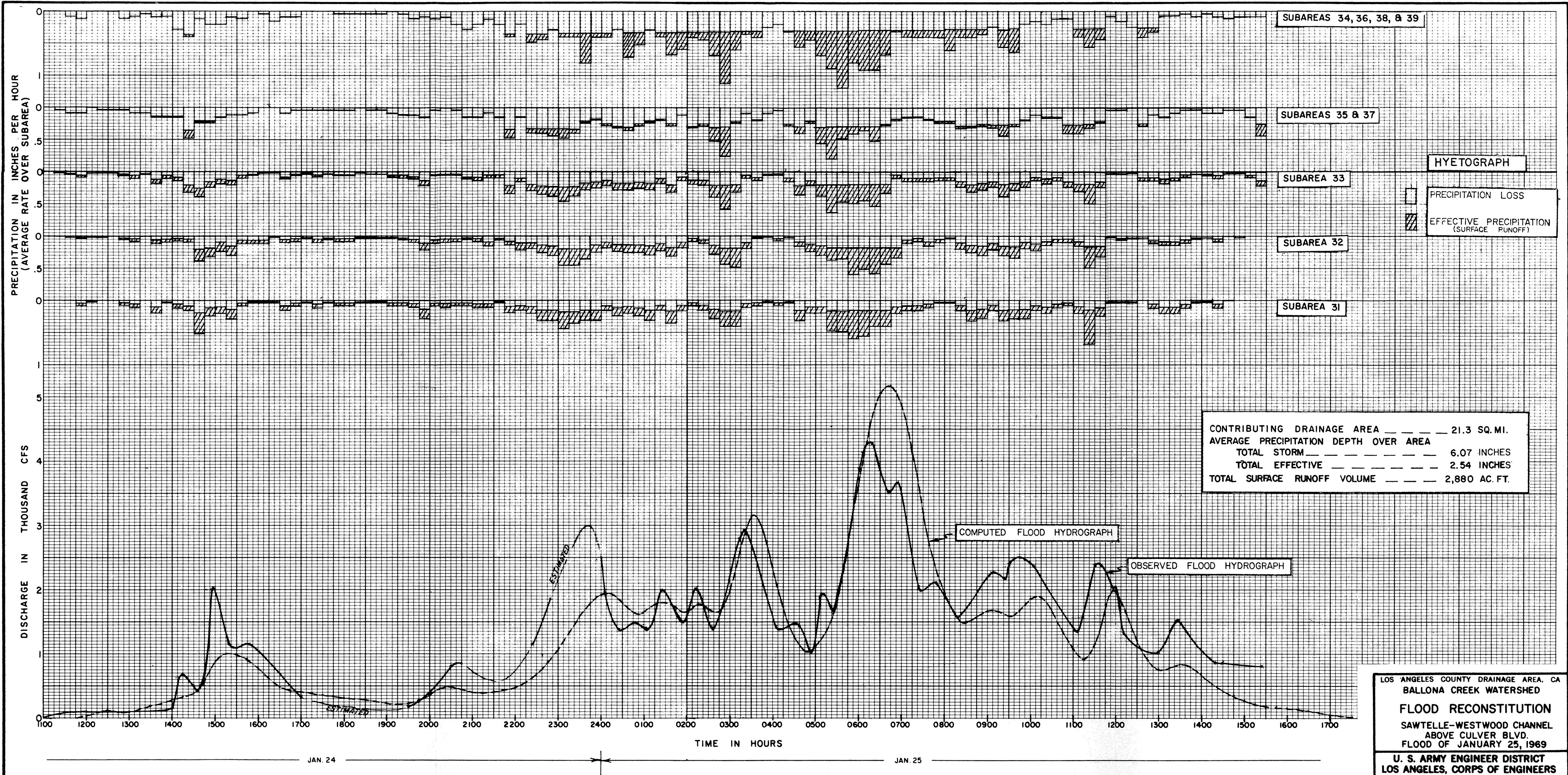
EFFECTIVE PRECIPITATION
(SURFACE RUNOFF)

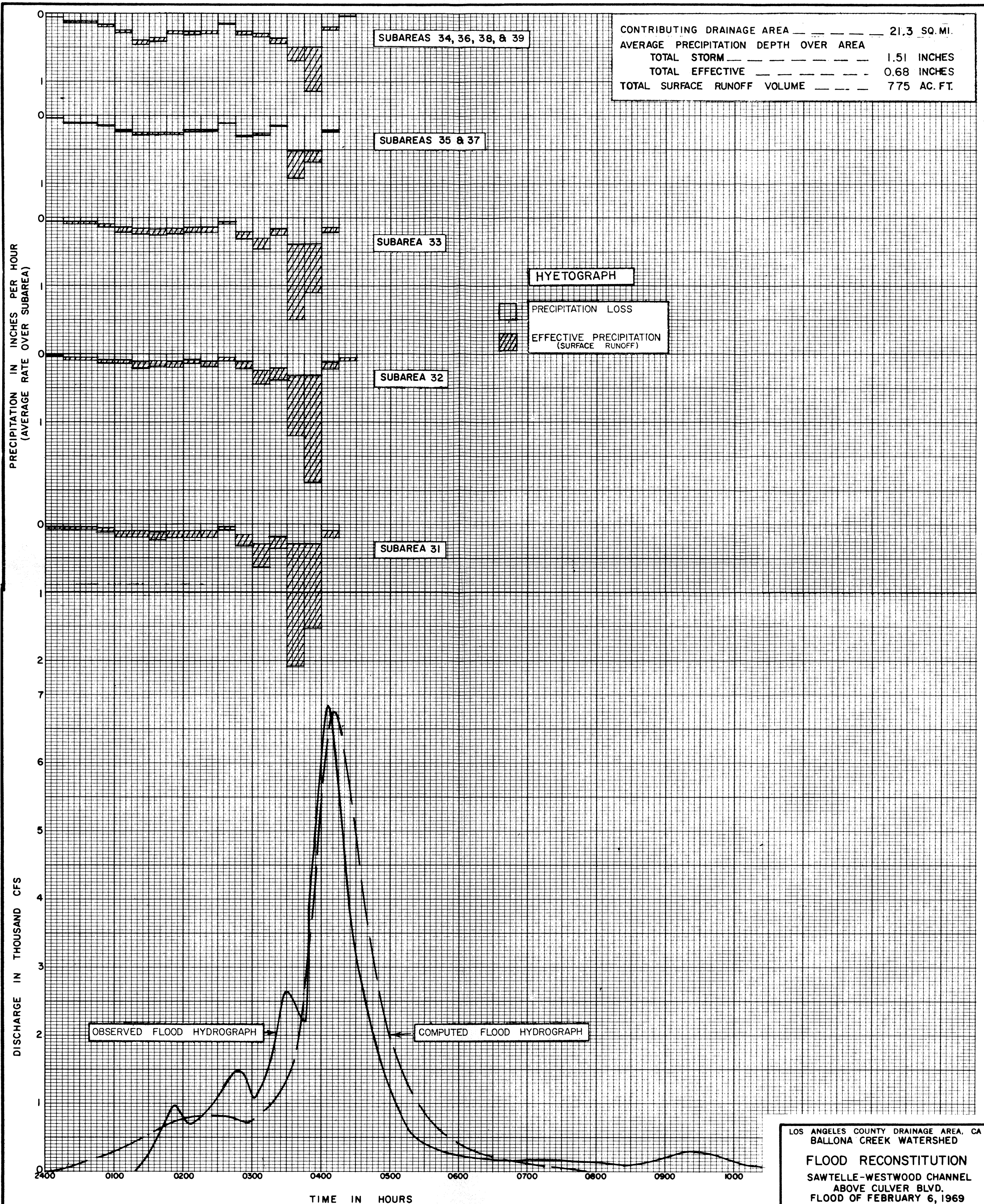
DISCHARGE IN THOUSAND CFS

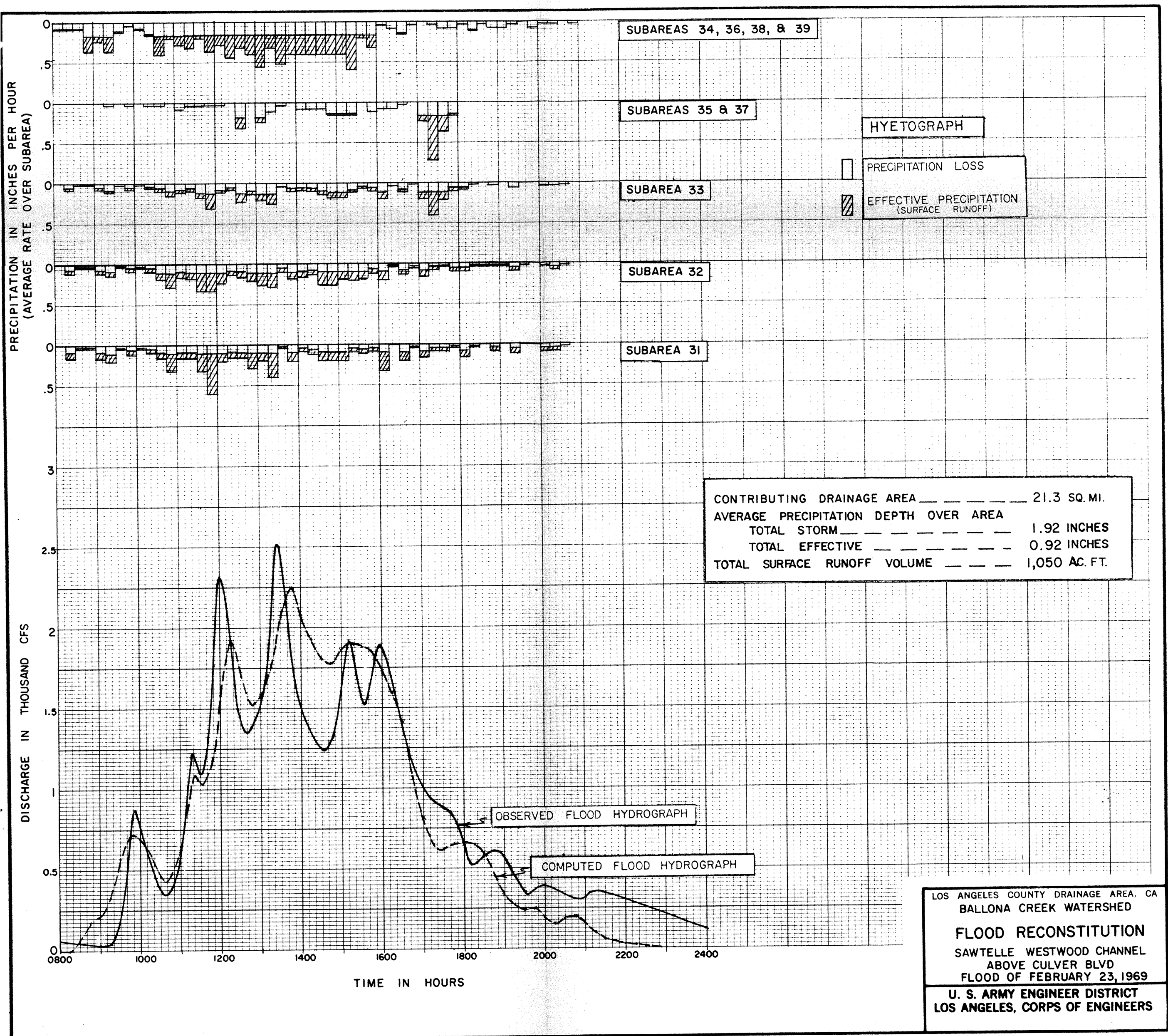


CONTRIBUTING DRAINAGE AREA	21.3 SQ. MI.
AVERAGE PRECIPITATION DEPTH OVER AREA	
TOTAL STORM	1.71 INCHES
TOTAL EFFECTIVE	1.02 INCHES
TOTAL SURFACE RUNOFF VOLUME	1,160 AC. FT.

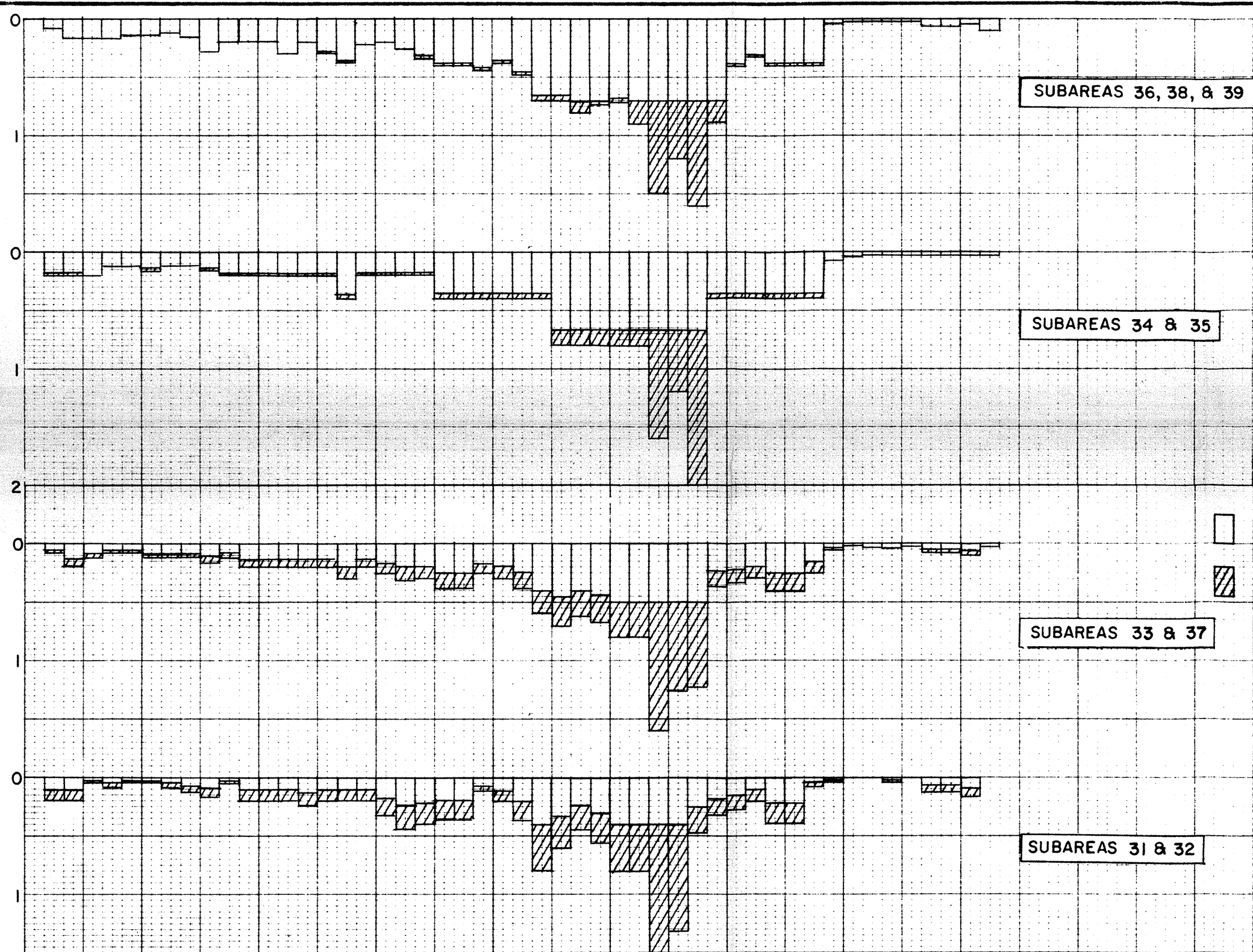
LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
FLOOD RECONSTITUTION
SAWTELLE WESTWOOD CHANNEL
ABOVE CULVER BLVD
FLOOD OF NOVEMBER 21, 1967
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS





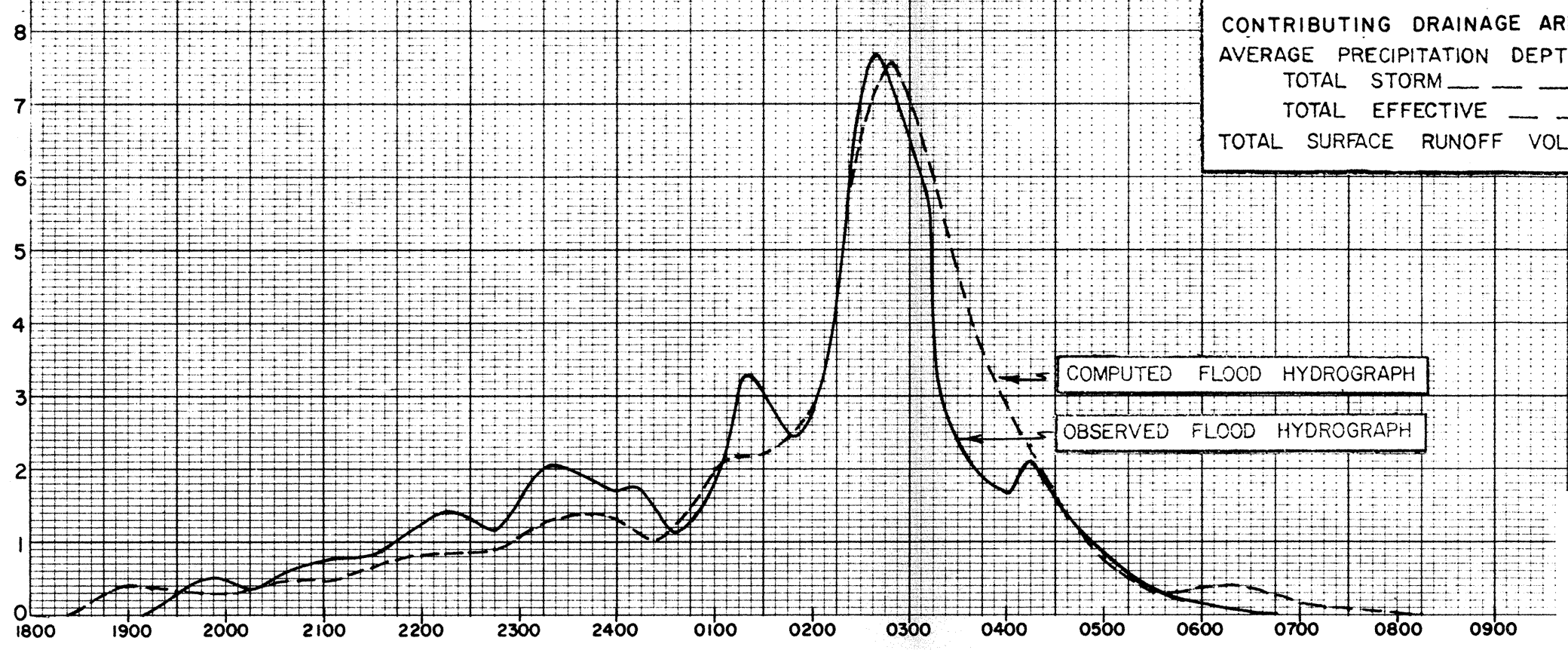


PRECIPITATION IN INCHES PER HOUR
(AVERAGE RATE OVER SUBAREA)



CONTRIBUTING DRAINAGE AREA ——— 21.3 SQ. MI.
 AVERAGE PRECIPITATION DEPTH OVER AREA
 TOTAL STORM ——— 4.10 INCHES
 TOTAL EFFECTIVE ——— 1.50 INCHES
 TOTAL SURFACE RUNOFF VOLUME ——— 1,700 AC. FT.

DISCHARGE IN THOUSAND CFS



TIME IN HOURS

DEC. 3

DEC. 4

LOS ANGELES COUNTY DRAINAGE AREA, CA
 BALLONA CREEK WATERSHED
 FLOOD RECONSTITUTION
 SAWTELLE WESTWOOD CHANNEL
 ABOVE CULVER BLVD
 FLOOD OF DECEMBER 4, 1974
 U. S. ARMY ENGINEER DISTRICT
 LOS ANGELES, CORPS OF ENGINEERS

		CONTRIBUTING			S	LAG	ESTIMATED $\bar{n}$
		AREA	L	L_{co}			
		SQ. MI.	MILES	MILES	FT./MI.	HOURS	
1.	SAN GABRIEL RIVER AT SAN GABRIEL DAM	162.0	23.2	11.6	350	3.3	0.050
2.	WEST FORK SAN GABRIEL RIVER AT COGSWELL DAM	40.4	9.3	4.2	450	1.6	.050
3.	SANTA ANITA CREEK AT SANTA ANITA DAM	10.8	5.8	2.5	690	1.1	.050
4.	SAN DIMAS CREEK AT SAN DIMAS DAM	16.2	8.6	4.8	440	1.5	.050
5.	EATON WASH AT EATON WASH DAM	9.5	7.3	4.4	600	1.3	.050
6.	SAN ANTONIO CREEK NEAR CLAREMONT	16.9	5.9	3.0	1,017	1.2	.055
7.	SANTA CLARA RIVER NEAR SAUGUS	355.0	36.0	15.8	140	5.6	.050
8.	TEMECULA CREEK AT PAUBA CANYON	168.0	26.0	11.3	150	3.7	.050
9.	SANTA MARGARITA RIVER NEAR FALLBROOK	645.0	46.0	22.0	105	7.3	.055
10.	SANTA MARGARITA RIVER AT YSIDORA	740.0	61.2	34.3	85	9.5	.055
11.	LIVE OAK CREEK AT LIVE OAK DAM	2.3	2.9	1.5	700	.8	.070
12.	TUJUNGA CREEK AT BIG TUJUNGA DAM	81.4	15.1	7.3	290	2.5	.050
13.	EAST FULLERTON CREEK AT FULLERTON DAM	3.1	3.2	1.7	140	.6	.035
14.	LOS ANGELES RIVER AT SEPULVEDA DAM	152.0	19.0	9.0	145	3.5	.050
15.	PACOIMA WASH AT PACOIMA DAM	27.8	15.0	8.0	315	2.4	.050
16.	ALHAMBRA WASH ABOVE SHORT STREET	14.0	9.5	4.6	85	.6	.015
17.	BROADWAY DRAIN ABOVE RAYMOND DIKE	2.5	3.4	1.7	100	.28	.015
18.	BALLONA CREEK AT SAWTELLE BLVD.	88.6	11.8	5.6	64	1.2	.020
19.	SAN JOSE CREEK AT WORKMAN MILL ROAD BRIDGE	81.3	23.7	9.1	75	2.4	.030

GUIDE FOR ESTIMATING BASIN FACTOR ($\bar{n}$)

$\bar{n}=0.200$: DRAINAGE AREA HAS COMPARATIVELY UNIFORM SLOPES AND SURFACE CHARACTERISTICS SUCH THAT CHANNELIZATION DOES NOT OCCUR. GROUND COVER CONSISTS OF CULTIVATED CROPS OR SUBSTANTIAL GROWTHS OF GRASS AND FAIRLY DENSE SMALL SHRUBS, CACTI, OR SIMILAR VEGETATION. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}=0.050$: DRAINAGE AREA IS QUITE RUGGED, WITH SHARP RIDGES AND NARROW, STEEP CANYONS THROUGH WHICH WATERCOURSES MEANDER AROUND SHARP BENDS, OVER LARGE BOULDERS, AND CONSIDERABLE DEBRIS OBSTRUCTION. THE GROUND COVER, EXCLUDING SMALL AREAS OF ROCK OUTCROPS, INCLUDES MANY TREES AND CONSIDERABLE UNDERBRUSH. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}=0.030$: DRAINAGE AREA IS GENERALLY ROLLING, WITH ROUNDED RIDGES AND MODERATE SIDE SLOPES. WATERCOURSES MEANDER IN FAIRLY STRAIGHT, UNIMPROVED CHANNELS WITH SOME BOULDERS AND LODGED DEBRIS. GROUND COVER INCLUDES SCATTERED BRUSH AND GRASSES. NO DRAINAGE IMPROVEMENTS EXIST IN THE AREA.

$\bar{n}=0.015$: DRAINAGE AREA HAS FAIRLY UNIFORM, GENTLE SLOPES WITH MOST WATERCOURSES EITHER IMPROVED OR ALONG PAVED STREETS. GROUND COVER CONSISTS OF SOME GRASSES WITH APPRECIABLE AREAS DEVELOPED TO THE EXTENT THAT A LARGE PERCENTAGE OF THE AREA IS IMPERVIOUS.

TERMINOLOGY

L = LENGTH OF LONGEST WATERCOURSE.

L_{co} = LENGTH ALONG LONGEST WATERCOURSE, MEASURED UPSTREAM TO POINT OPPOSITE CENTER OF AREA.

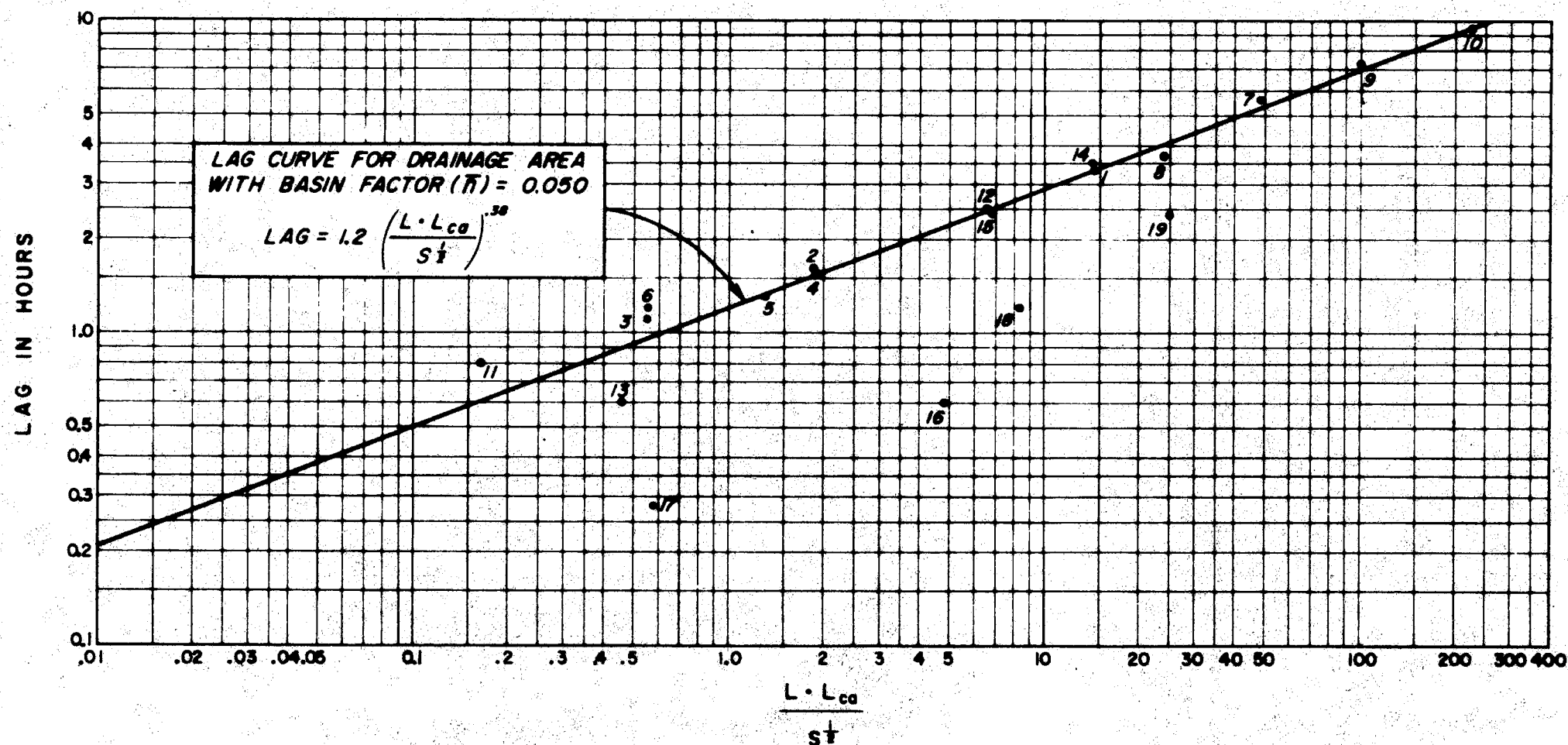
S = OVER-ALL SLOPE OF LONGEST WATERCOURSE BETWEEN HEADWATER AND COLLECTION POINT.

LAG = ELAPSED TIME FROM BEGINNING OF UNIT PRECIPITATION TO INSTANT THAT SUMMATION HYDROGRAPH REACHES 50% OF ULTIMATE DISCHARGE.

$\bar{n}$ = VISUALLY ESTIMATED MEAN OF THE n (MANNING'S FORMULA) VALUES OF ALL THE CHANNELS WITHIN AN AREA.

NOTE: TO OBTAIN THE LAG (IN HOURS) FOR ANY AREA, MULTIPLY THE LAG OBTAINED FROM THE CURVE BY:

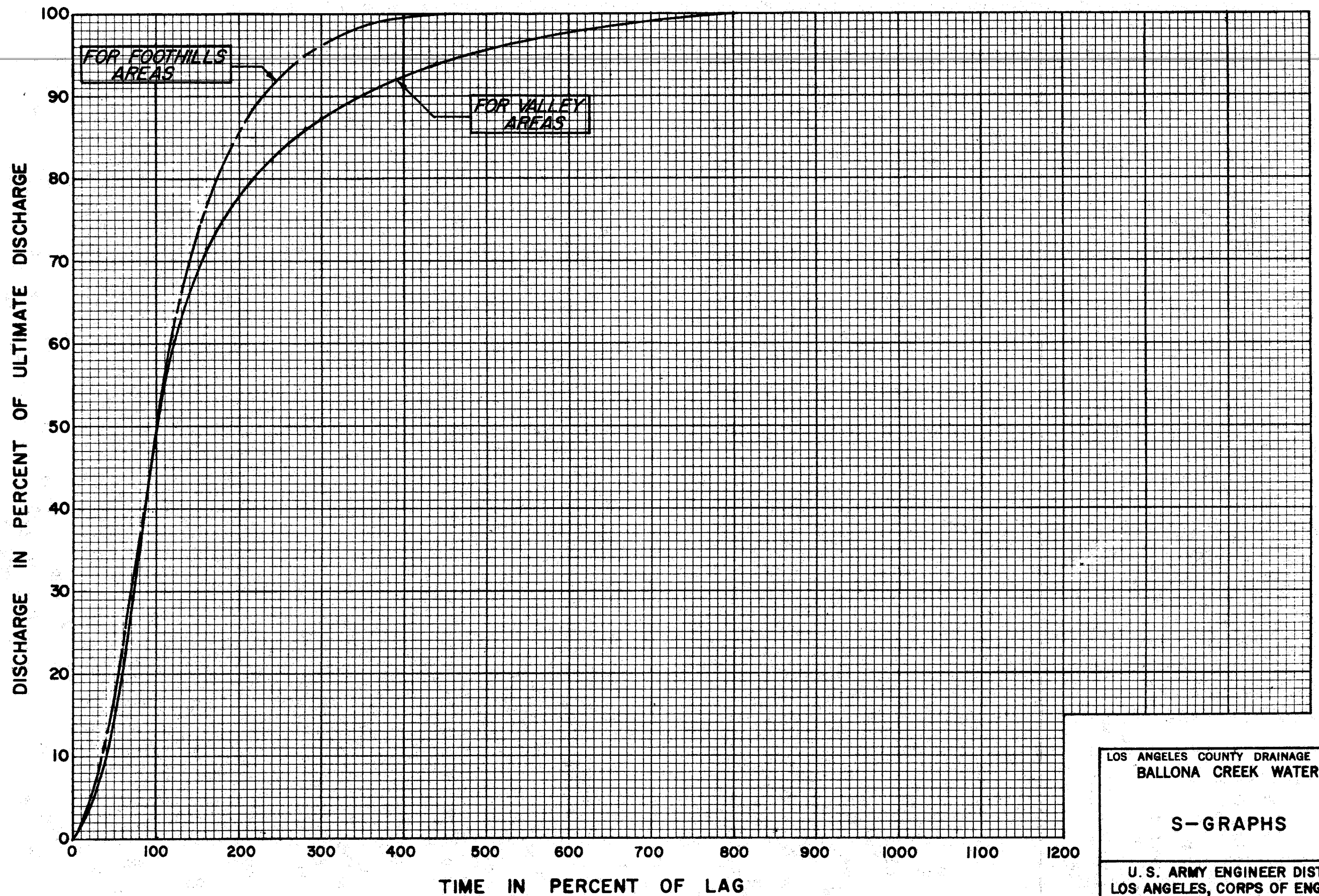
$$\frac{\bar{n}}{0.050} \text{ OR } 20\bar{n}$$



LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED

LAG RELATIONSHIPS

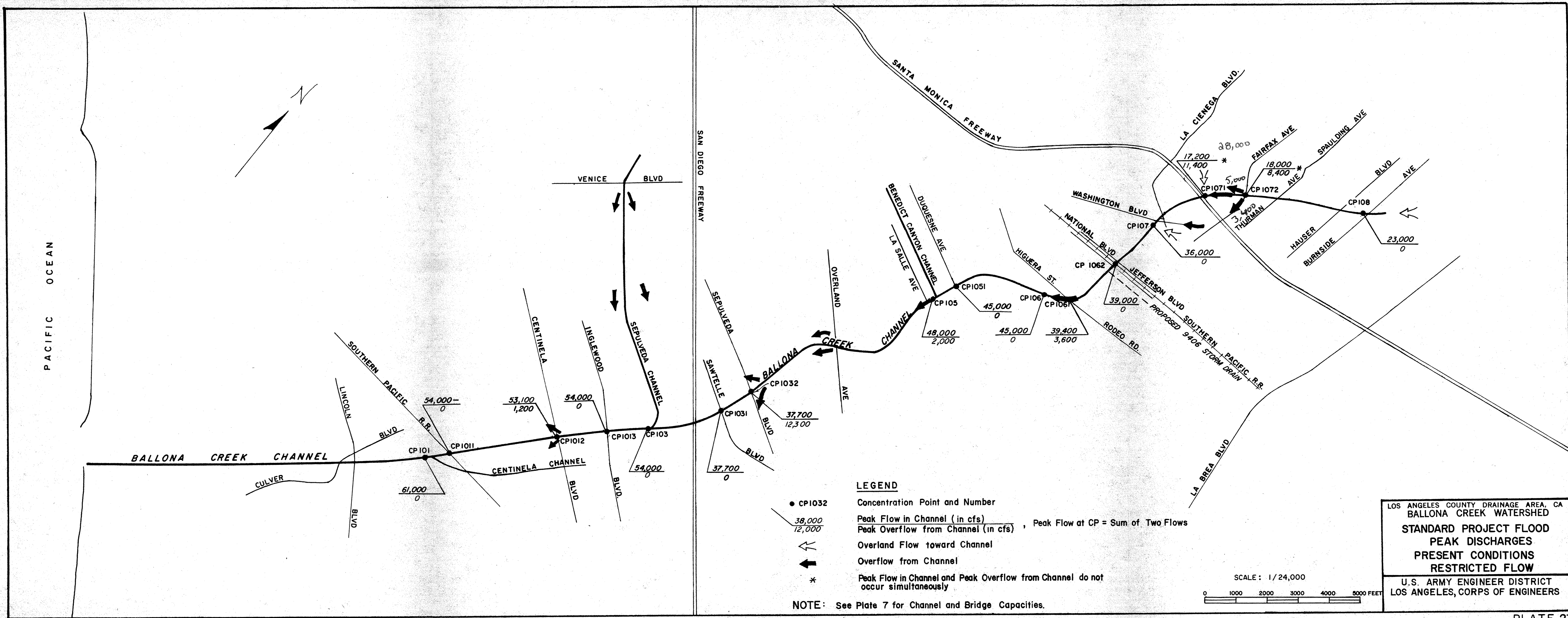
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED MARCH 1973

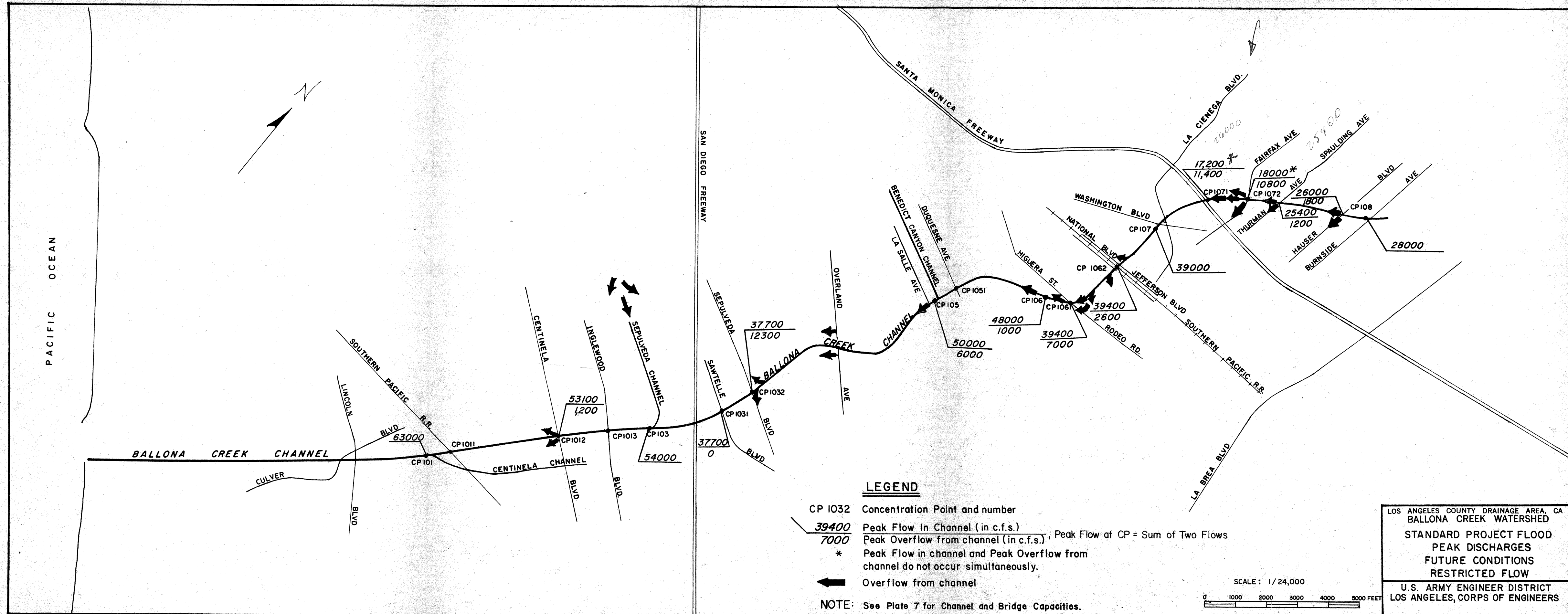


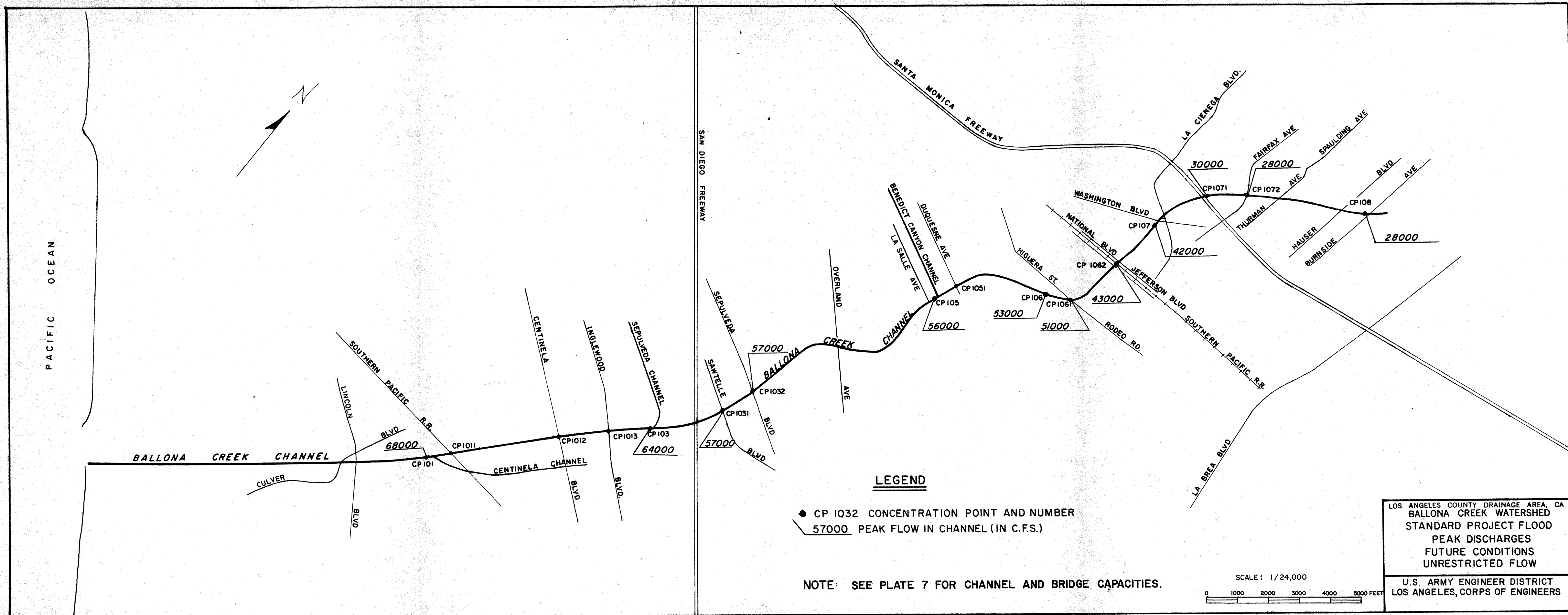
LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED

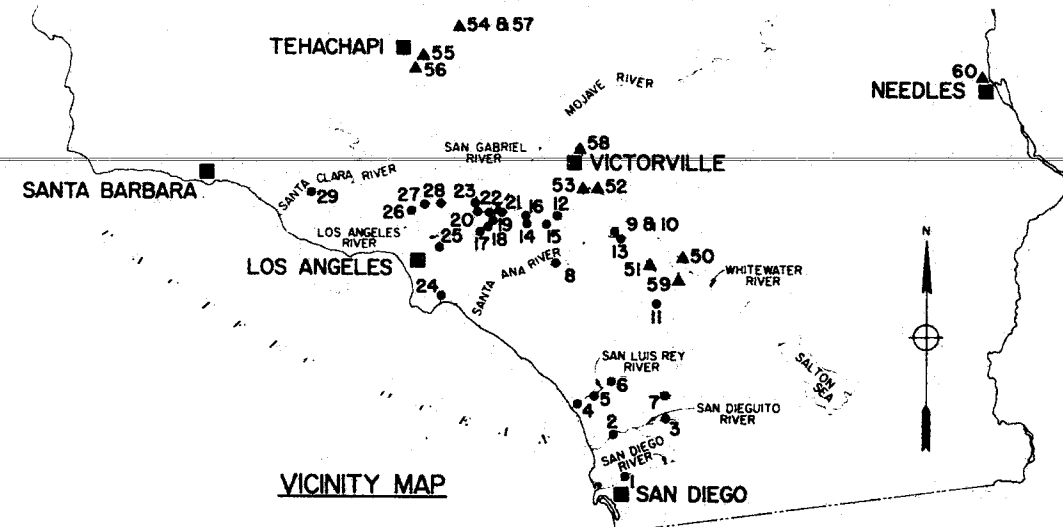
S-GRAPHS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS







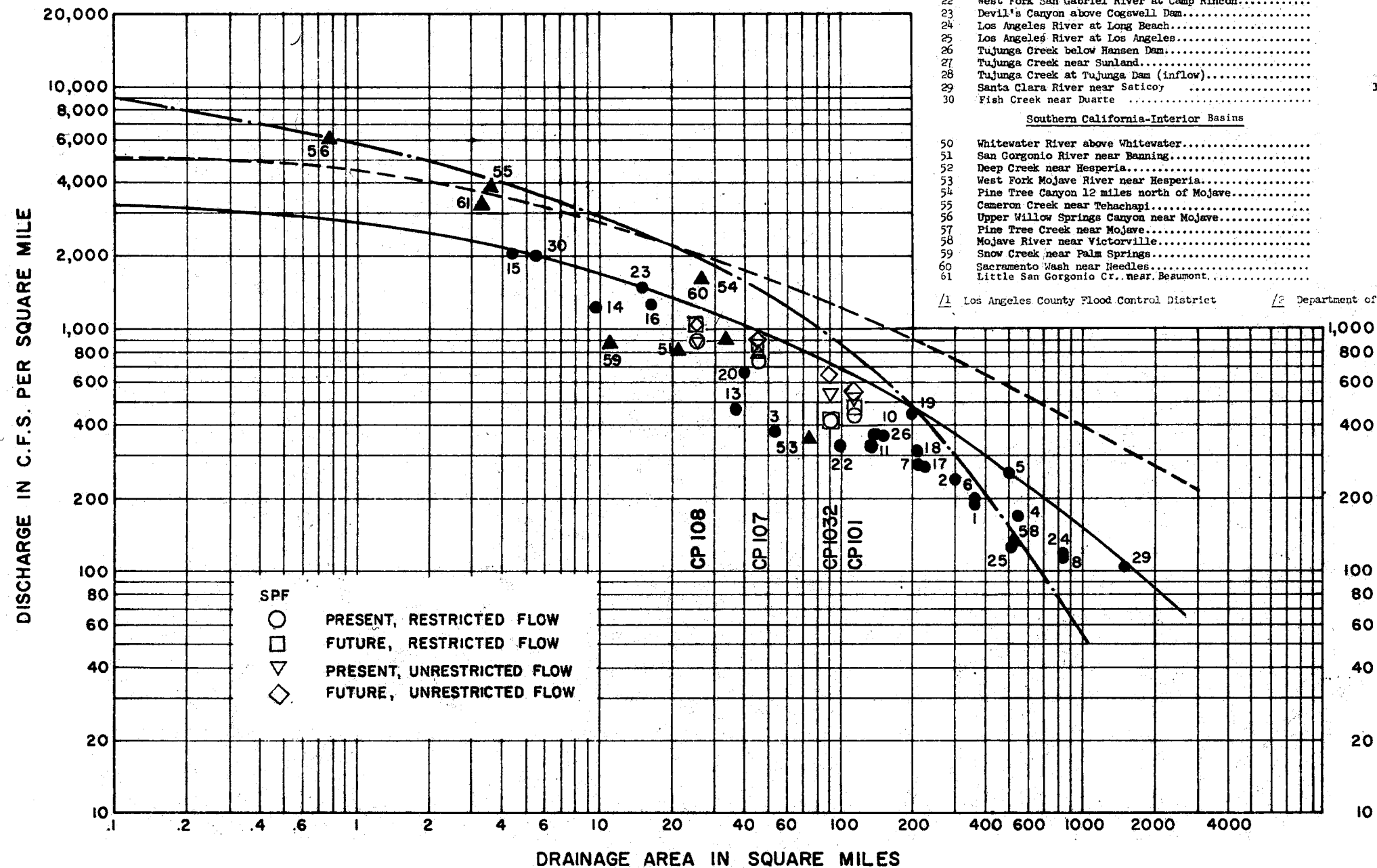


NO.	STREAM AND LOCATION	DRAINAGE AREA Square miles	PEAK DISCHARGE Cubic feet per second	DATE	AUTHORITY
Southern California-Pacific Slope Basins					
1	San Diego River near Santee.....	377	70,200	27 Jan 1916	USGS WSP 447
2	San Dieguito River near Bernardo.....	299	72,100	do.....	USGS WSP 426
3	Santa Ysabel Creek near Mesa Grande.....	53.9	21,100	do.....	USGS WSP 426
4	San Luis Rey River at Oceanside.....	557	95,600	do.....	USGS WSP 447
5	San Luis Rey River at Bonsall.....	512	128,000	23 Feb 1891	USGS WSP 426
6	San Luis Rey River near Pala.....	373	75,300	27 Jan 1916	USGS WSP 426
7	San Luis Rey River near Mesa Grande.....	209	58,600	do.....	USGS WSP 426
8	Santa Ana River at Riverside Narrows.....	858	100,000	2 Mar 1938	USGS WSP 844
9	Santa Ana River near Mentone.....	144	52,300	do.....	USGS WSP 844
10	do.....	144	53,700	23 Feb 1891	USGS WSP 447
11	San Jacinto River below North Fork near San Jacinto.....	141	45,000	16 Feb 1927	USGS WSP 844
12	Lytle Creek near Fontana.....	47.9	35,900	25 Jan 1969	USGS Calif 1969
13	Mill Creek near Yucaipa.....	38.1	18,100	2 Mar 1938	USGS Calif 1969
14	Cucamonga Creek near Upland.....	10.1	14,100	25 Jan 1969	USGS Calif 1969
15	Day Creek near Etiwanda.....	4.6	9,450	do.....	USGS Calif 1969
16	San Antonio Creek near Claremont.....	16.9	21,400	2 Mar 1938	USGS WSP 844
17	San Gabriel River at Foothill Blvd.....	230	61,800	do.....	USGS WSP 844
18	San Gabriel River below Morris Dam.....	211	65,700	do.....	USGS Calif 1963
19	San Gabriel River at San Gabriel Dam.....	202	90,000	do.....	USGS WSP 844
20	San Gabriel River at Cogswell Dam.....	40.4	26,900	do.....	USGS WSP 844
21	East Fork San Gabriel River near Camp Bonita.....	88.2	46,000	do.....	USGS Calif 1963
22	West Fork San Gabriel River at Camp Rincon.....	102	34,000	do.....	USGS Calif 1963
23	Devil's Canyon above Cogswell Dam.....	15.4	23,000	do.....	/1
24	Los Angeles River at Long Beach.....	832	102,000	25 Jan 1969	USGS Calif 1969
25	Los Angeles River at Los Angeles.....	514	67,000	3 Mar 1938	USGS Calif 1963
26	Tujunga Creek below Hansen Dam.....	150	54,000	do.....	USGS Calif 1963
27	Tujunga Creek near Sunland.....	106	50,000	do.....	USGS Calif 1963
28	Tujunga Creek at Tujunga Dam (inflow).....	81.4	35,000	do.....	USGS Calif 1969
29	Santa Clara River near Saticoy.....	1,595	165,000	25 Jan 1969	USGS Calif 1969
30	Fish Creek near Duarte.....	6.4	13,000	do.....	USGS Calif 1969
Southern California-Interior Basins					
50	Whitewater River above Whitewater.....	51.4	42,000	2 Mar 1938	USGS WSP 844
51	San Geronimo River near Banning.....	21.2	17,000	do.....	USGS WSP 844
52	Deep Creek near Hesperia.....	137	46,600	do.....	USGS WSP 844
53	West Fork Mojave River near Hesperia.....	74.8	26,100	do.....	USGS WSP 844
54	Pine Tree Canyon 12 miles north of Mojave.....	35.0	59,500	12 Aug 1931	/2
55	Cameron Creek near Tehachapi.....	3.59	13,500	30 Sep 1932	/1
56	Upper Willow Springs Canyon near Mojave.....	0.81	4,900	do.....	/1
57	Pine Tree Creek near Mojave.....	33.5	30,000	23 Aug 1961	USGS Calif 1963
58	Mojave River near Victorville.....	530	70,600	2 Mar 1938	USGS Calif 1963
59	Snow Creek near Palm Springs.....	11.0	9,500	Feb 1927	/3
60	Sacramento Wash near Needles.....	27.0	43,000	17 Aug 1938	USGS
61	Little San Geronimo Cr. near Beaumont.....	3.23	11,000	25 Feb 1969	USGS Calif 1969

/1 Los Angeles County Flood Control District

/2 Department of Water and Power, Los Angeles

/3 Coachella Valley Water District



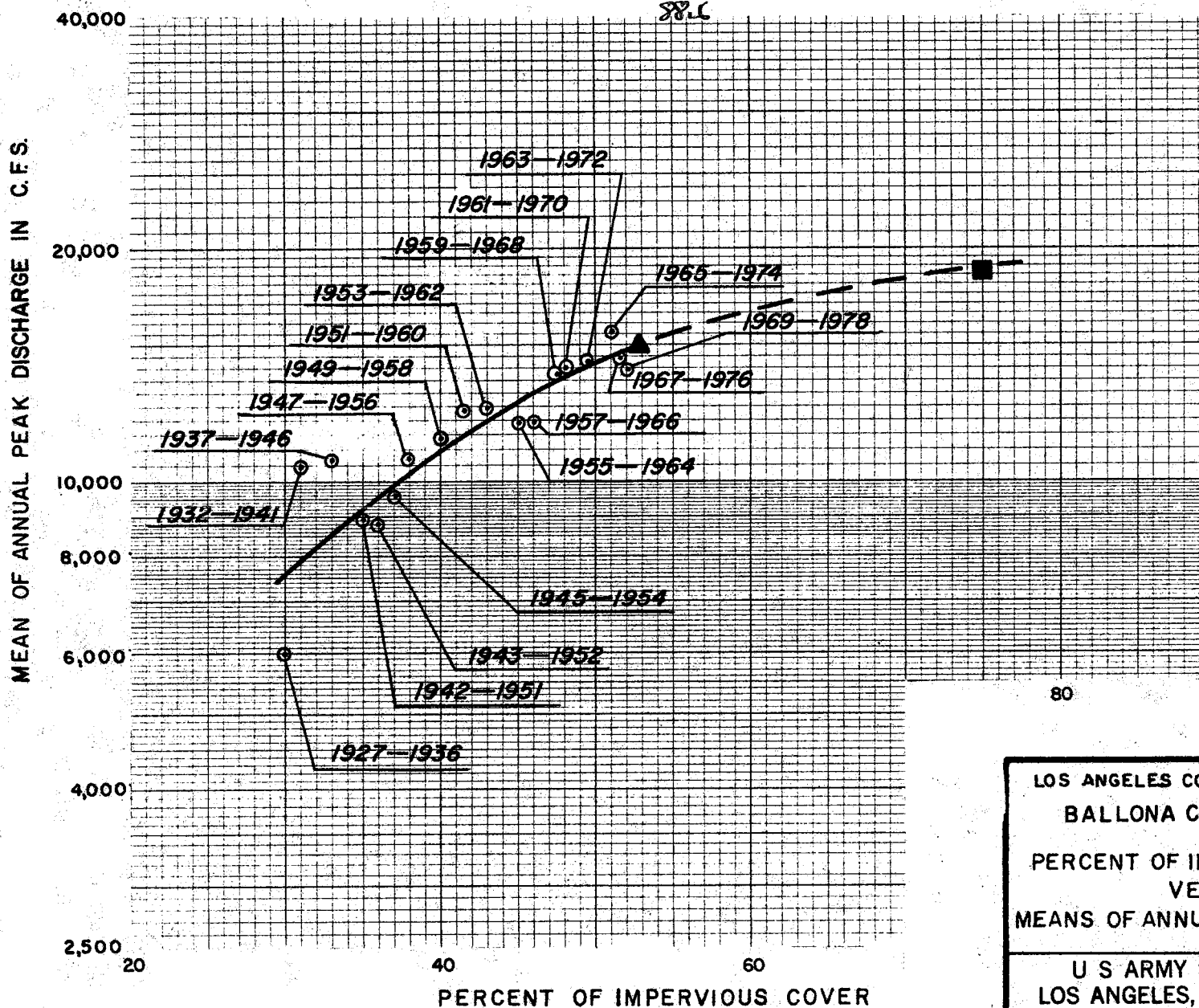
LEGEND

- RECORDED OR ESTIMATED PEAK DISCHARGE-PACIFIC SLOPE BASINS.
- ▲ RECORDED OR ESTIMATED PEAK DISCHARGE-INTERIOR BASINS.
- CREAGER ENVELOPING CURVE OF MAXIMUM FLOODS IN THE U. S.
- C OF E ENVELOPING CURVE OF RECORDED OR ESTIMATED PEAK DISCHARGES FOR SOUTHERN CALIFORNIA COASTAL STREAMS.
- C OF E ENVELOPING CURVE OF RECORDED OR ESTIMATED PEAK DISCHARGES FOR SOUTHERN CALIFORNIA DESERT STREAMS.

LEGEND

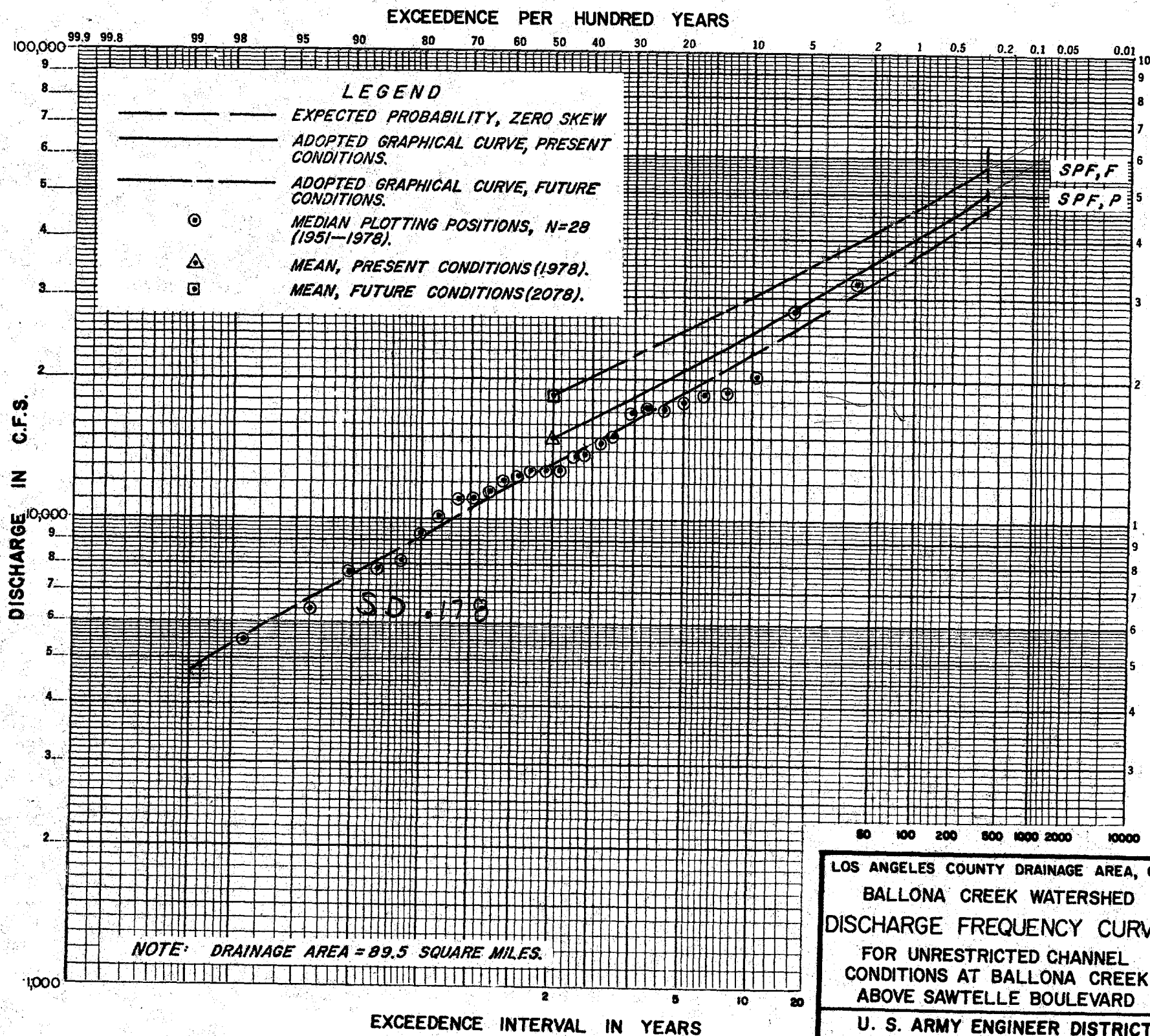
- 10 YEAR MEAN.
- ▲ ESTIMATED 1978 WATERSHED PERCENT IMPERVIOUS COVER.
- ESTIMATED 2078 WATERSHED PERCENT IMPERVIOUS COVER.

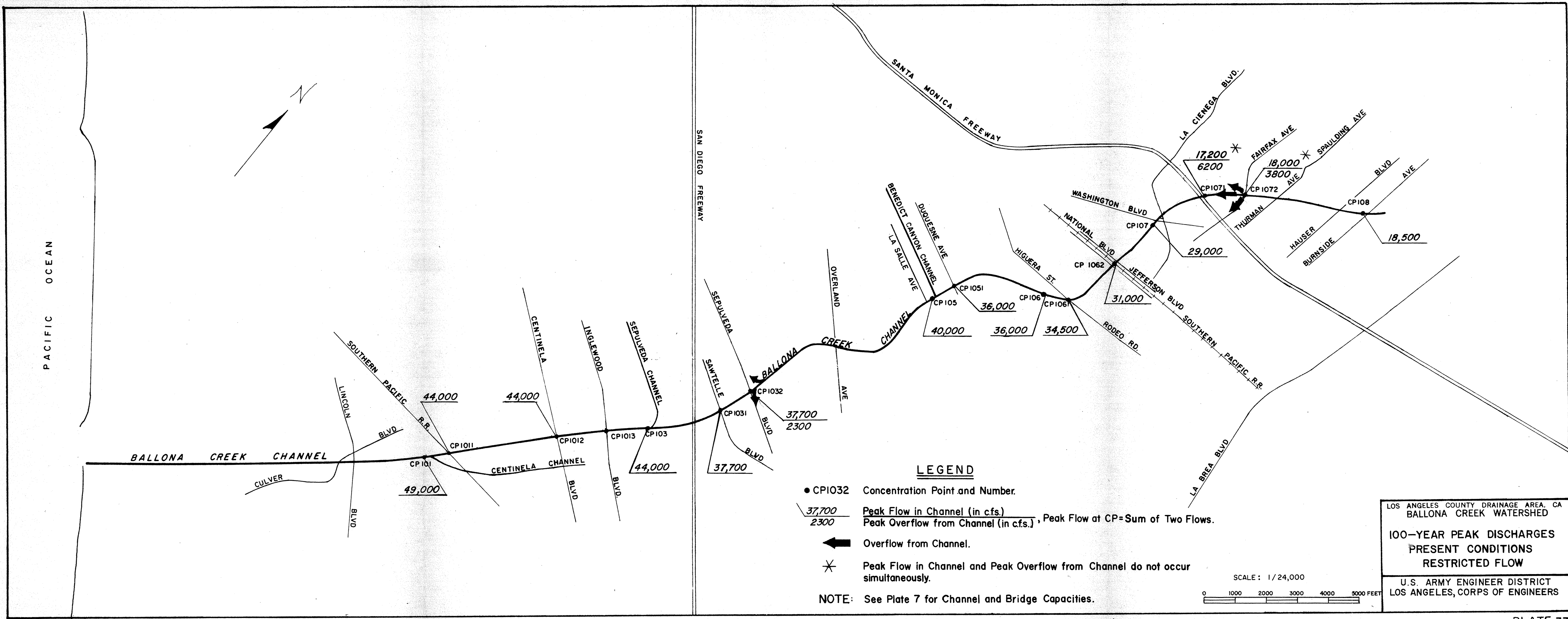
LOCATION: BALLONA CREEK ABOVE SAWTELLE BOULEVARD,
DRAINAGE AREA = 89.5 SQUARE MILES.

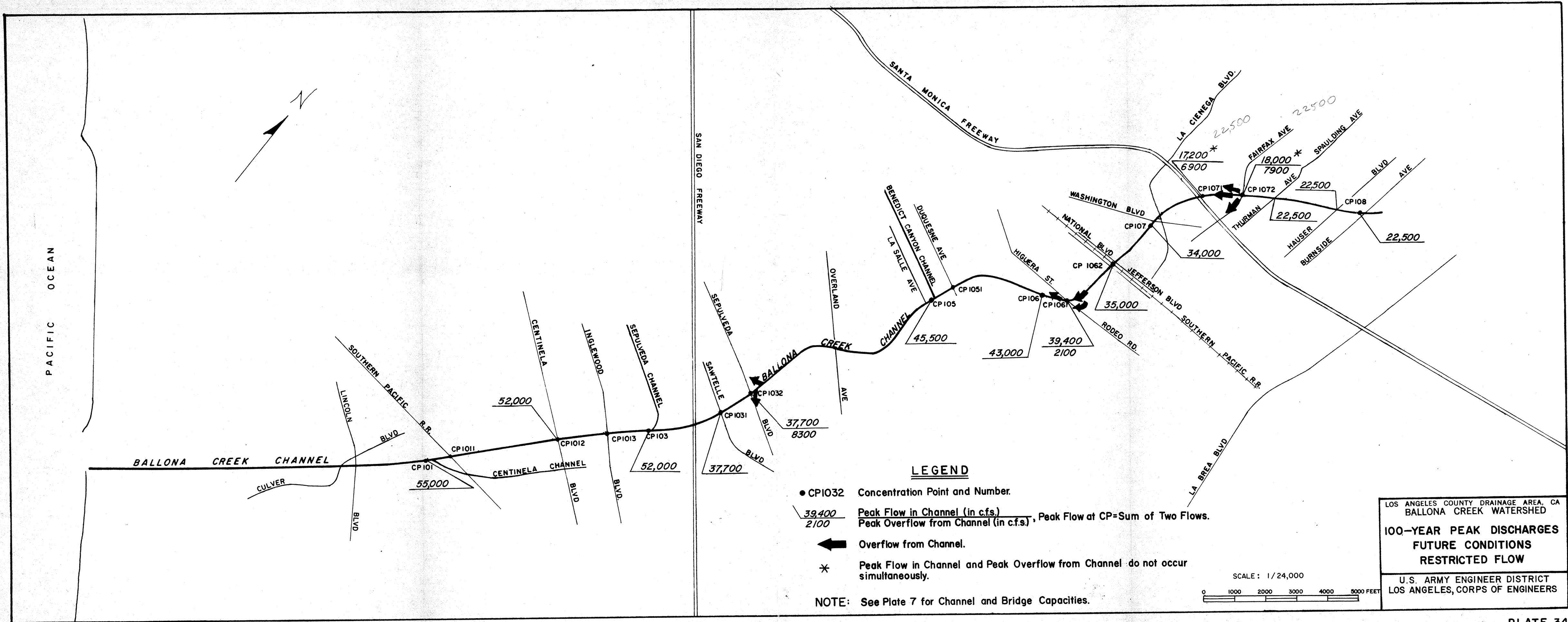


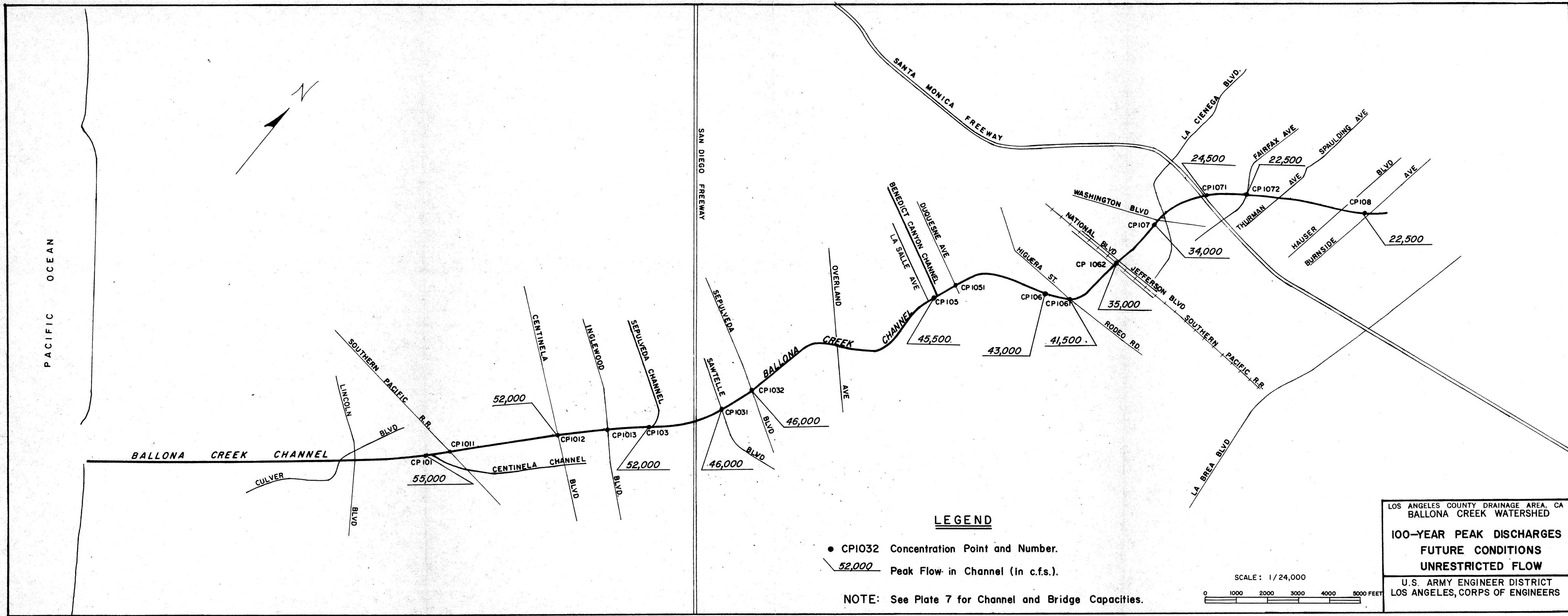
LOS ANGELES COUNTY DRAINAGE AREA, CA.
BALLONA CREEK WATERSHED
PERCENT OF IMPERVIOUS COVER
VERSUS
MEANS OF ANNUAL PEAK DISCHARGES

U S ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY DESIGN MEMO NO.





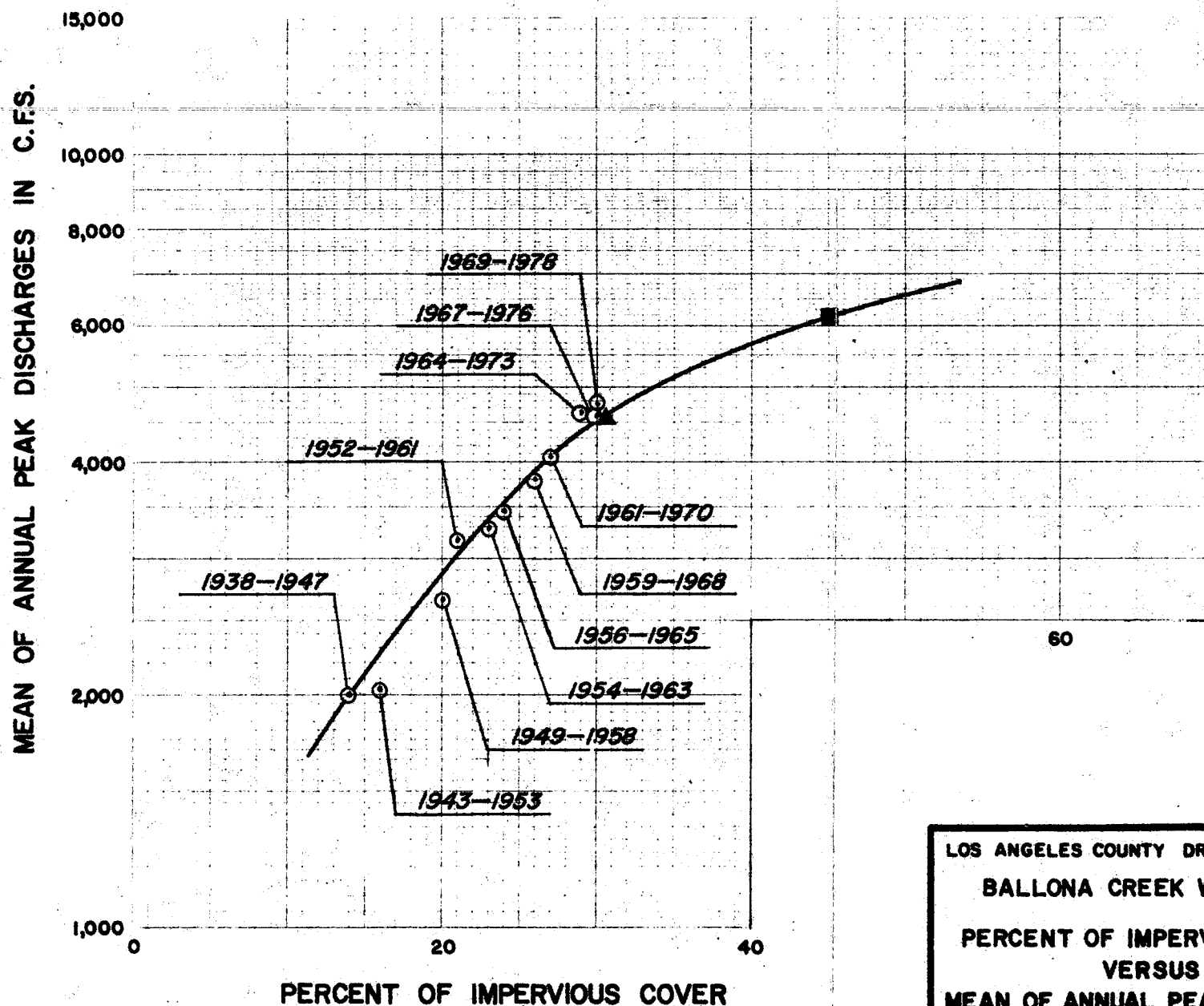




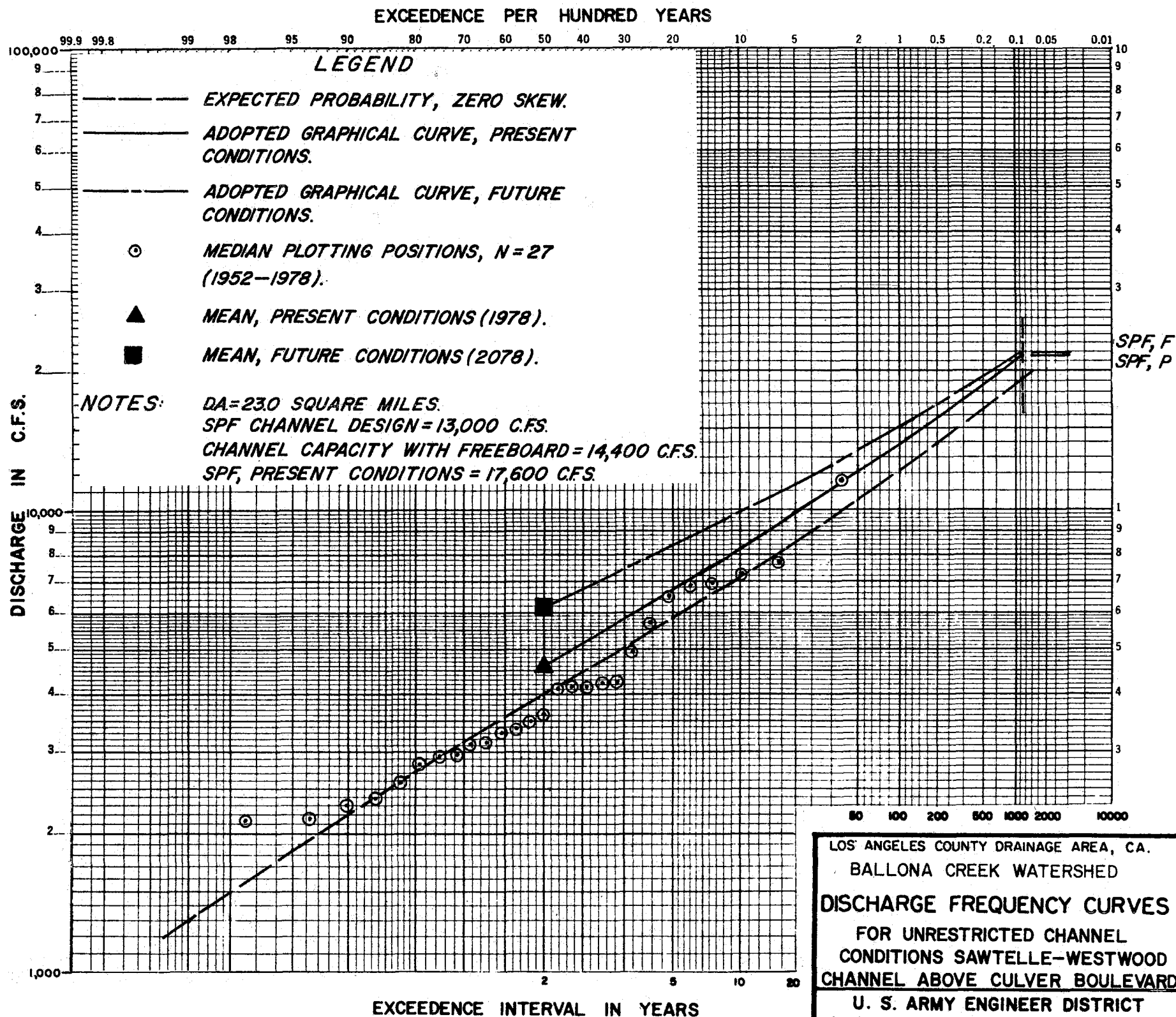
LEGEND

- 10 YEAR MEAN.
- ▲ ESTIMATED 1978 WATERSHED PERCENT IMPERVIOUS COVER.
- ESTIMATED 2078 WATERSHED PERCENT IMPERVIOUS COVER.

LOCATION: SAWTELLE-WESTWOOD CHANNEL ABOVE CULVER BOULEVARD.
DRAINAGE AREA = 23.0 SQUARE MILES.



LOS ANGELES COUNTY DRAINAGE AREA, CA
BALLONA CREEK WATERSHED
PERCENT OF IMPERVIOUS COVER
VERSUS
MEAN OF ANNUAL PEAK DISCHARGES
U S ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT
TO ACCOMPANY REPORT DATED:



LOS ANGELES COUNTY DRAINAGE AREA, CA.
 BALLONA CREEK WATERSHED
DISCHARGE FREQUENCY CURVES
 FOR UNRESTRICTED CHANNEL
 CONDITIONS SAWTELLE-WESTWOOD
 CHANNEL ABOVE CULVER BOULEVARD
 U. S. ARMY ENGINEER DISTRICT
 LOS ANGELES, CORPS OF ENGINEERS

